SURFACE COATING AND STORAGE EFFECTS ON MANDARIN (*Citrus unshiu* Marc.) FRUIT QUALITY

A thesis presented in partial fulfilment of the requirements
for the degree of
Master of Applied Science at
Massey University

Latchmi Prasad

April 1996

ABSTRACT

Satsuma mandarin grown in the marginal climate of New Zealand has a niche market in Japan and properly managed this trade has good prospects for expanding. The internal quality of satsuma usually do not reach the minimum requirement of a total soluble solids (TSS) to titratable acid ratio of 10:1 during the harvest season with conventional management, thus lowering the export quantity. Two cultivars of mandarin fruit from Kerikeri, Gisborne and Bay of Plenty were picked on 4-5 dates to record the pattern of quality change and to investigate the effect of storage temperature, storage period and surface coatings on the keeping quality and acceptability of mandarin.

The TSS and colour of fruit remained mostly similar while the titratable acidity showed a downward trend as the harvest season progressed in the three districts. The TSS:acid ratio increased due to the progressive decrease in juice acidity. At no harvest did mandarin fruit reached the desired TSS:acid ratio of 10:1. 'Silverhill' had higher a TSS:acid ratio than 'Miyagawa' during the harvest season in all districts. Fruit from Gisborne had the highest ratio while Bay of Plenty had the lowest.

The juice TSS remained similar during storage except in late harvested 'Miyagawa' fruit it increased after 3 weeks cold storage storage at 6°C plus one week at 20°C. Titratable acidity always decreased as the storage period progressed. Provided fruit of both cultivars is not harvested too early it can be improved to meet Japanese market internal quality standards by about 1 month in cold storage. This results from a 20-30% decline in juice titratable acidity.

Fruit dipped in one of the three coatings carnauba, 'Citruseal' (polyethylene) and 'Citrus Gleam' (shellac) had similar TSS, titratable acid, TSS:acid ratio and colour during 6 weeks cold storage at 6°C and one week at 20°C. During this period the coated fruit accumulated high levels of acetaldehyde, ethanol and carbon dioxide and low levels of oxygen, especially when coated with carnauba or shellac. The resultant off-flavours made the juice unpalatable within as little as 3 weeks at 6°C. Holding fruit at 20°C accelerated these undesirable changes. Fruit dipped in shellac had higher levels of off-flavours present compared to sprayed fruit. Increasing the shellac coating by a double dip accentuated its effect on fruit oxygen and carbon dioxide in storage.

Coated fruit consistently had a lower level of weight loss compared to uncoated during cold storage (6°C) and at 20°C. Fruit stored at 60% relative humidity had >5% weight loss which is commercial unacceptable.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude and sincere thanks to my supervisor Dr G.S. Lawes, senior lecturer in the Plant Science Department of Massey University for his patient guidance, encouragement throughout the course of this study. His advice was most helpful and friendly.

I greatly appreciate the help from C.Yearsley and Sue Jolly for their kind assistance in laboratory work of the experiments and to the staff and student of the Plant Science Department for their valuable assistance in many ways.

I wish to thank Dr Woolley, Dr D.E.J. Wood, A. Currie, M. Currie, P. Fleming, L. Pulupol of Plant Science Department, Mrs M. Hoseason of Works and Services Department and Mrs R. Neill of Marketing Department for participating in the sensory evaluation. I am gratefully indebted to Ms C.B.M. Groenendijk of Food Technology for her expert advce on the procedure of sensory evaluation.

I would also like to thank the following growers for supplying experimental fruit: R. Davies, J. Willets from Kerikeri, D. Smith, R. Jefferson from Bay of Plenty and C. Lewis from Gisborne.

I gratefully acknowledge the New Zealand Ministry of Foreign affairs and Trade for awarding me the scholarship and the Fiji Government for approving my study leave to under take this study.

To my family, wife Pravin and children Shalesma and Shalvin for their love, moral support, encouragement and understanding during the course of my study.

And finally to almighty God through whose blessing I was able to complete my study.

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1 GENERAL INTRODUCTION

Citrus (*Citrus p*) belong to the family Rutaceae and subfamily Aurantioideae and the genus citrus includes several important fruit such as oranges, mandarins, limes, lemons and grapefruit. Citrus originated in south east Asia and is now grown in the tropical - subtropical belt from 40° latitude north Island of New Zealand represents about the coolest extreme in which citrus may be grown commercially and Thailand is among the hottest year round climates supporting commercial orchards of citrus (Reuther, 1967). Citrus fruit are popular worldwide for their flavour and nutritional value and is one of the major fruit produced in the world. In addition to fresh fruit there are many processed citrus products of which concentrated orange juice is the most important due to the trend in consumer preference (Baldwin, 1993). The recognized international demand for easy peel citrus fruit has helped stimulate interest in increased commercial production of Satsuma mandarins in New Zealand.

Satsuma mandarins (*Citrus unshiu* Marc) have been grown in New Zealand for many years since it has a well - established niche in the New Zealand market because they are easy - peeling, seedless and the first citrus of the season (Sale, 1985). An export market niche has been identified in Japan from April to August where there is very low production and high demand for easy peel citrus fruit. In the year ending June 1995, approximately $NZ1.693m (F.O.B) worth of mandarins, an increase of 279% compared to 1994 have been exported to Japan (Anon. 1995).

Scientists have attempted to objectively quantify the quality of mandarin and oranges by using total soluble solids (TSS) and the TSS to titratable acidity (TA) ratio (Sinclair, 1961). Maturity studies, both in New Zealand and overseas, indicate that when the TSS:A ratio exceeds 7.5:1, fruit are acceptable to consumers but fruit with TSS:A ratio of 9:1 - 12:1 are preferred. Similarly oranges attained their best flavour in New Zealand when TSS levels exceeded 11% and fruit were considered to be insipid below 9.0 - 9.5% TSS (Fletcher and Hollies, 1965).

Successful marketing of fruit in Japan is dependent on fruit with good size (80-120g), excellent appearance and high internal quality of at least 10% TSS and acid of 0.8% (Harty and Anderson, 1995). The major problem in New Zealand is that growers have been unable to produce fruit of sufficient quality for export to the lucrative Japanese market (Martin, 1991). Fruit of mandarin in New Zealand are of marginal quality due to low sugar to acid ratio of 7.1 to 9.1. In a New Zealand citrus conference in 1993, a remit that the minimum TSS to acid ratio level for Satsuma mandarins be raised from 7.0:1 to 7.5:1 in the interest of better fruit quality was lost because the growers did not want to shorten their harvest season (Anon. 1993).

The growth rate and time of ripening of citrus fruit is markedly influenced by the total heat available during the growing season. Since Kerikeri and Auckland in the north are a little warmer than Bay of Plenty and Gisborne, Navel and Valencia oranges produced in the northern areas were found to be significantly superior in TSS levels and juice contents than oranges from Bay of Plenty and Gisbrone (Fletcher and Hollies, 1965). Similar results were found in South Africa where a higher TSS: acid ratio was obtained in the warmer district of Malelane compared with Zebediela (Giltillan et al. 1971).

The internal quality of citrus fruit may be improved significantly by long term programmes of importation or breeding of improved cultivars and rootstocks. In the immediate future improvement of satsuma mandarin fruit quality through management techniques such as thinning and microclimate modification which involves reflective mulches, water stress, low crop load, nutrition and plastic house production have been encouraging .

From initial trials carried out by the DSIR, it was found that if fruit were protected from weight loss, fruit remained in satisfactory condition for at least 6 weeks at 5°C and a further 2 weeks at 20°C (Beever, 1989). Sensory evaluation and chemical analysis of waxed fruit after post harvest treatment and storing at low temperatures of 5-20°C for 4 to 8 weeks showed they retained acceptable flavour and also increased their internal quality (Cohen et al. 1991).

Citrus fruit are coated (waxed) to minimize weight loss, physiological deterioration and improve appearance by imparting a skin gloss (Ben-Yehoshua et al., 1970). These coatings act as a barrier to water vapour thus reducing the transpiration rates. Coatings also act as an additional barrier layer, increasing the fruit's skin resistance to gas vapour diffusion, thus hindering oxygen and carbon dioxide exchange and reducing respiration rate (Hagenmaier and Baker, 1995; Banks, 1984). Coatings reduce internal oxygen and increase carbon dioxide concentrations in fruit and in many cases result in development of off-flavours (Cohen et al., 1990). This change in flavours results from the inhibition of oxygen and carbon dioxide exchange from the coated fruit to the external atmosphere. Under these conditions, anaerobic respiration produces ethanol and aceteldehyde resulting in the development of off-flavours (Davis and Hofmann, 1973; Hagenmaier and Shaw, 1992). Much of the work has largely been on orange and grapefruit discussing the effects of coatings on the internal and external quality of the fruit.

The purpose of this study is to investigate the changes in mandarin fruit quality during the harvest period in the three citrus growing districts in New Zealand and the effects of storage period, temperature and coatings on post harvest quality changes. The effect of various coatings and application methods on quality and internal atmosphere composition changes during various storage periods in mandarin was also investigated.

CHAPTER 2 LITERATURE REVIEW

2.1 Fruit Composition

Citrus fruit are hesperidium berries having leathery peel surrounding the edible portion of the fruit. The fruit peel consists of an outer coloured exocarp (flavedo) and an inner white spongy mesocarp (albedo). The edible portion comprises the interior portion of the carpels which expand into segments containing juice vesicles and seeds (Davies and Albrigo, 1994). Juice within the vesicles contains essentially all the titratable acids and other soluble materials such as amino acids and salts (Table 1)(Baldwin, 1993).

Most citrus like other fruit are primarily water but also contain over 400 other constituents including carbohydrates, organic acids, amino acids, ascorbic acid and minerals and small quantities of flavonoids, carotenoids, volatiles and lipids. Citrus fruit are low in proteins, starch and fats (Davies and Albrigo, 1994). Much of the consumption of citrus is linked to the potential health related benefits contained in the juice (low fat, high mineral and vitamin C) (Nagy and Attaway, 1980).

In most citrus growing regions, fruit quality standards which determine minimum levels of palatability and commercial acceptability have been established. The flavour and palatability of citrus fruits is a function of relative levels of Total soluble solids (TSS), total acidity, presence or absence of various aromatic or bitter constituents, juiciness and toughness of the pulp vesicles (Davies and Albrigo, 1994). Citrus fruit are deemed to be marketable when a minimum TSS:TA ratio is attained although relative levels of TSS also affect palatability. Fruit or juice having high TSS: TA ratio and high TSS taste very sweet, whereas those with low ratios and TSS are tart. Fruit with high ratio and low TSS taste insipid. For fresh citrus fruit, external appearance (colour and blemish) and fruit size also contribute to the acceptance by consumers (Nito and Iwamasa, 1992).

Table 1. Composition of California 'Valenica' oranges. The values in the first half of the table are expressed in g (100g^{-1}) while those in the second half are expressed in mg (100g)$^{-1}$

	Peel	Edible portion	Juice
Acid (citric)	0.29	0.75	1.02
Ash	0.78	0.48	0.34
Fat	0.23	0.30	0.29
Moisture	72.52	85.23	87.11
Protein	1.53	1.13	1.00
Sugar			
Reducing	5.56	4.69	4.99
Sucrose	1.99	4.41	4.73
Total	7.55	9.10	9.72
TSS	15.69	13.06	12.59
Ascorbic acid	136.5	39.5	43.5
Biotin	0.005	0.001	trace
Calcuim	161.0	36.7	9.5
Carotenoids	9.9	3.4	2.8
Iron	0.8	0.8	0.3
Magnesuim	22.2	11.5	11.3
Phosphorus	20.8	21.8	19.5
Potassuim	212.0	173.0	163.0
Soduim	3.0	1.3	0.7
Sulfur	21.0	11.5	8.5

Source: Erickson (1968) and Davies and Albrigo (1994)

2.1.1 Total soluble solids

Total soluble solids (TSS), which include carbohydrates, organic acids, proteins, fats and various minerals, comprise 10 to 20% of the fresh weight of citrus fruit (Erickson, 1968). Carbohydrates account for 70-80% of the TSS in the fruit. According to Davies and Albrigo (1994) the major groups of carbohydrates in citrus fruits include monosaccharides (glucose, fructose), oligosaccharides (sucrose) and polysaccharides (cellulose, starch, hemicelluloses, pectins).

TSS is one of the characteristics commonly utilized as an indicator of maturity of citrus. There are two methods for determining juice TSS: measuring the specific gravity with a hydrometer, or the refractive index with a refractometer. A hydrometer calibrated in percentage TSS placed in a cylinder containing about 500ml of strained juice is allowed to float for a few minutes, and then read. Temperature of the juice is determined at the same time so the hydrometer reading can be calibrated to a standard temperature, usually 20°C.

A hand refractometer, usually with juice scale calibrated at either 20 or 25°C utilizes only one or two drops of juice and is much faster (Harty et al., 1992). Individual carbohydrates can be measured by liquid chromatography. Daito and Sato (1985) using liquid chromatography identified sucrose, fructose and glucose as predominant sugars in early 'Okitsu Wase' and standard 'Silverhill' cultivars. During maturation, the total sugars in cvs Okitsu Wase and Silverhill increased from 2.81 to 10.89 and 4.41 to 9.47 mg per 100 ml of juice respectively.

2.1.2 Acidity

The accumulation of citric acid in the juice vesicles of citrus fruit is an important factor to the grower since it directly affects the quality of the fruit and palatability of the juice. The vesicles have been suggested as the site of citric acid synthesis (Huffaker and Wallace, 1959; Bean and Todd, 1960; Yen and Koch, 1990). Acids could be translocated from other parts of the plant, such as roots, leaves, and fruit peel where organic acid synthesis has been demonstrated (Huffaker and Wallace, 1959). Huffaker and Wallace (1959) proposed that the dark fixation of CO_2 is part of a major pathway of citric acid synthesis in citrus fruit vesicles (Fig 1).

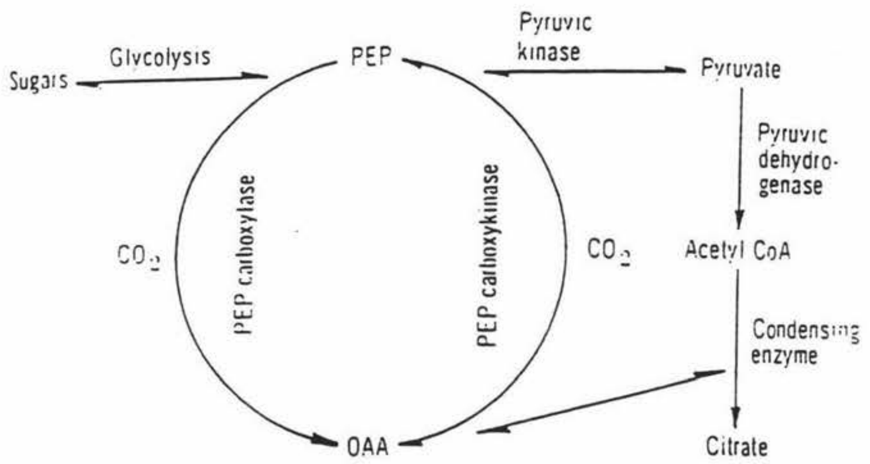


Fig. 1. A proposed major pathway of citric acid synthesis in citrus fruit vesicles. (Huffaker and Wallace, 1959).

Citrate formation may be traced from the oxidation of sugars to pyruvate, hence to formation of phosphoenoly pyruvate (PEP) or to a decarboxylation forming acetyl CoA. Carbon dioxide is incorporated in the presence of PEP carboxylase or PEP carboxykinase to form oxaloacetic acid (OAA) which then condenses with acetyl-CoA to form citrate (Reuther et al., 1968; Ting and Attaway, 1971).

There are several ways of expressing acidity of fruit. One of the most common is titratable acidity determined by titrating a known volume of juice with a standard solution of 0.1 N sodium hydroxide with phenolphthalein as indicator. Juice pH may be measured with a pH meter or indicator paper.

Organic acids of citrus fruits have been studied using silicic-acid and gas chromatography and juice of mature fruits are generally characterised by a predominance of citric acid, and peel tissues by malonic and malic acid . Acids succinic, adipic, isocitric, oxalic, lactic, aconitic, ketoglutaric and benzoic also have been detected in low levels (Clements,1963, 1964; Sasson and Monselise, 1977). Rasmussen (1964) found citric acid was the major acid of the pulp from approximately eight weeks after fruit set until after maturity whereas he found very little citric acid in the peel at any period in the growth cycle of orange.

A steady decline in titratable acidity occurs as sweet citrus fruits develop and ripen, and during storage (Chandler and Kefford, 1970). Clements (1964) found navel orange fruit remaining on the tree beyond maturity were organoleptically unacceptable due to low acid and a benzaldehyde like off-flavour. Sasson and Monselise (1977) reported that only citric and malic acids decreased while the other acids tended to increase in Shamouti orange during storage. Malic acid decreased faster than citric acid.

2.1.3 Volatiles

Fruit when mature contain a range of compounds which may be highly or slightly volatile. These compounds, though being present in small amounts are of major importance in terms of flavour and their measurement in evaluation of quality and deterioration during storage and marketing have become important. According to Baldwin (1993) the essence of citrus flavour is a complex mixture of volatile compounds of which some 200 have been identified. Some components contributing to citrus flavour are listed in table 3. The most important volatiles are the esters and aldehydes, followed by alcohols, ketones and hydrocarbons (Bruemmer, 1975 cited by Baldwin, 1993).

Davis (1970) found ethanol and acetaldehyde content of 'Hamlin', 'Pineapple', and 'Valencia' oranges and 'Marsh' and 'Ruby red' grapefruit juice increased rapidly as the Florida growing season progressed. Daito and Sato (1985) measured a gradual increase in ethanol and acetaldehyde during maturation in satsuma mandarin. Shaw et al (1992) measured up to 24 fold increases in some volatile components in Dancy Mandarin and mandarin hybrid in a controlled atmosphere of nitrogen and carbon dioxide. Citrus fruit coated with waxes or films showed significant increases in volatile components considered important to fresh citrus flavour (Nisperos-Carriedo, 1990: Davis and Hofmann, 1973: Hagenmaier and Baker, 1994).

2.2 Factors affecting fruit composition

The major factors affecting the composition of citrus are the climatic and horticultural conditions under which they are grown and there are many complex interrelationships among the various factors (Reitz and Embleton, 1984).

Component	Oranges	Grapefruit	Tangerine	Lemon/lime
Aldehydes	geranial neral acetaldehyde decanal octanal sinensal (E)-2-pentenal	acetaldehyde decanal	acetaldehyde decanal octanal α-sinensal	geranial neral nonanal
Esters	ethyl acetate ethyl propionate methyl butanoate ethyl 2-methyl-butanoate ethyl-3-hydroxy-hexanoate	ethyl acetate methyl butanoate ethyl butanoate	dimethyl anthranilate	*methyl epijasmonate neryl acetate geranyl acetate
Alcohols and thiols	ethanol (E)-2-hexenol (Z)-3-hexenol linalool α-terpineol	1-p-menthene-8-thiol	ethanol thymol	α-bisabolol geraniol
Ketones	1-carvone 1-penten-3-one	nootkatone		
Hydrocarbons	d-limonene myrcene α-pinene valencene	limonene	τ-terpinene β-pinene	τ-terpinene β-pinene bergamotene **caryophyllene germacrene B
Ethers		ether		*carvyl ethyl *8-p-cymenyl ethyl ether *fenchyl ethyl ether *myrcenyl ethyl ether *α-terpinyl ethyl ether
Bitter components	limonin	naringin		

* Lemon only
** Lime only

Table 2 Components important to citrus juice flavour (Baldwin, 1993)

2.2.1 Maturation

Citrus maturation consists of a growth stage and a maturation stage. During the growth stage organic acid accumulation in the fruit is mainly attributed to early blockage of the citric acid cycle where citric acid is produced, by either a lack of or inhibition of the aconitase enzyme which would normally break down the citric acid (Kimball, 1984). During maturation Sinclair and Ramsey (1944) showed that though the absolute amount of the organic acids remained unchanged concentration of the citric acid decreased. This was partly the result of an increase in size of the orange fruit and accumulation of water which diluted the acid concentration.

Hilgeman et al.,(1967a,b) followed the maturation of Valencia oranges in Arizona during the period from the 10th to the 15th month after blossoming and found the fruit increased in weight and juice content, while the juice increased in TSS content. As oranges mature on the tree the concentration of juice soluble solids slowly increase and acidity steadily decreases. This results in oranges becoming progressively sweeter and less tart as they mature. Studies in New Zealand indicate that once the Brix : acid ratio reaches about 7.5 : 1, the orange fruits are acceptable to the average palate. Fruits continue to improve in flavour if left on the tree after they reach minimum maturity and oranges achieve their most pleasant flavour when TSS : acid ratios reach about 9:1 to 12:1. In New Zealand, Navel oranges mature to a mean TSS : acid ratio of 7.5:1 during about the last week in July and as the harvesting season progresses this steadily increases to 12:1 to 14:1 by the end of the season in mid October (Fletcher and Hollies, 1965).

Satsuma mandarin, the first citrus to come on to the market in New Zealand reach commercial maturity (7:1) in early May and harvest period ranges through to August. Although fruit acidity levels decline over the harvest period, the Brix:acid ratio remain at minimal range of 7.2:1-8.4:1 (Dawes and Martin, 1991).

2.2.2 Climate

Climate particularly light, temperature and water has a pronounced effect on internal and external fruit quality. In South Africa, fruit on trees on north facing slopes tend to mature earliest, followed by east or west facing slopes (Bower,1994). Sites and Reitz (1955) found TSS and TSS:acid ratio in fruit of Valencia oranges varied mainly with the amount of shading, the height of the fruit on the tree and the direction of exposure to light. Fruits exposed to light tended to have higher TSS but no relationship was found between titratable acid and exposure to light.

Temperature has a major impact on all facets of citrus growth and development. Reuther (1973) showed the growth of citrus shoots and roots was greatest at temperatures of 25 - 31°C and ceased below 12°C. Cool temperatures (10 - 15°C) before flowering increase the number of flowers produced by citrus trees but delay the flowering date, and during fruit growth produce smaller and flatter Satsuma mandarins than warmer conditions (Richardson et al., 1991) . Jones (1962) monitored changes in TSS, TA and the TSS:TA ratio over an eight year period for Washington navel in California and found considerable year to year variation in these characteristics which was closely related to heat unit accumulation (hours of temperature above 12-8°C). Kimball (1984) also observed a strong positive correlation between TSS:TA ratio and temperature accumulation after bloom for Navel oranges. The total heat available during the growing season has a marked influence on the growth rate, maturation and internal quality of citrus in New Zealand (Dawes and Martin, 1991; Fletcher and Hollies, 1965). Oranges mature earlier in Australia and California (warmer temperatures), normally have a higher TSS to acid ratio and have a longer harvesting season than New Zealand where temperatures are cooler. Oranges have also been shown to improve in quality with an increase in heat units in New Zealand citrus districts. Oranges from Kerikeri a warmer district (1795 - 2107 day degrees, base temperature of 12°C) had a higher TSS and juice content than from less warm districts of Bay of Plenty (1347 - 1696 day degrees) and Gisborne (1219 - 1638 day degrees) (Fletcher and Hollies, 1965). However average temperatures in the middle of summer are approximately 8°C lower than those areas of Japan where satsumas are grown, largely due to both lower maximum and minimum temperatures in New Zealand (Fig 1). Due to these low temperatures, satsuma fruit are often of marginal quality since the TSS:acid ratio in the fruit are low.

In Japan extremely high quality Satsuma fruit for the off-season market are produced under plastic cover by intensive temperature control using heaters to raise the temperature and ventilation fans to decrease the temperature automatically at each phase of growth (Nito and Iwamasa, 1992). Plastic mulching under the trees in New Zealand has increased canopy surface area and promoted earlier fruit maturation and higher yields in oranges due to extension of root growth with warmer soil conditions (Richardson et al, 1991). Juice of trees mulched with reflective foil had significantly higher TSS, with no difference in acidity compared to bare soil, thus had a significantly higher TSS:acid ratio throughout fruit maturation and at harvest (Richardson et al., 1993). Studies of Satsuma grown in an unheated plastic tunnel house showed relatively small improvements in the orchard microclimate produced higher yields of early high quality fruit (Anderson, 1991; Martin, 1991).

Pigmentation is a very important component in the visual acceptability of a fruit and it is the appearance of the fruit on which consumers largely base their decision to buy. In fruit which yellow during ripening there is a change in background colour produced by the rapid disappearance of chlorophyll and enhanced carotenoid biosynthesis as chloroplasts are transformed into chromoplasts. Pigments responsible for fruit skin colour are chlorophyll (green), carotenoids and flavonoids (yellow) and anthocyanins (red) (Gorski and Creasy, 1977; Hansen, 1956).

In the citrus industry chlorophyll degradation is important because in the market fruit are considered fully mature with best eating quality once all chlorophyll is lost. Changes in peel colour from green to orange in attached citrus fruit is a result of the disappearance of chlorophyll followed by a build up of carotenoid (Eilati et al, 1969). Loss of chlorophyll in orange fruit maturing on the tree is dependent upon day temperature below 20°C (Goldschmidt, 1980; Jahn, 1976). In the tropics citrus fruit remain green all the year around because of high temperatures though internal maturation has been attained. Knee et al (1988) reported oranges lost chlorophyll faster at 25°C than at 15°C so that after two weeks at 15°C many oranges were still green. Storage at 8°C markedly inhibited chlorophyll changes compared to 20°C for Shamouti oranges (Eilati et al 1969).

2.1.3. Cultivars

Breeding and selection of cultivars to meet the performance and quality requirement of each locality is an on going process for improvement in the industry. In New Zealand only those citrus cultivars that require a lower accumulated heat total to achieve an acceptable quality succeed, such as 'Navel' oranges (Sale, 1992). Dawes and Martin (1991) found that 'Silverhill', the standard industry cultivar had the best flavour and reached the highest TSS:acid ratio (7.2 to 8.4) during 1984-1987 when compared with other cultivars.

The internal quality of fruit is also dependent on cultivars. Gardner and Reece (1960) observed differences in Florida grown oranges where acidity ranged from 0.82% to 0.54% for 'Australian' and 'Washington' navel and total soluble solids ranged from 11.0 for 'Dream' to 9.84% for 'Summer field' respectively.

2.1.4 Rootstock

Rootstocks have a significant effect on fruit quality of a number of fruits eg citrus, apple, pears and avocado. Cultivars of citrus budded onto vigorous rootstocks including rough lemon, Palestine sweet lime, *Citrus macrophylla*, *C. pennivesiculata*, Rangpur lime and citron generally have larger fruit with thicker peel, rough peel texture and lower concentrations of TSS and titratable acidity (TA) (Fallahi et al 1989: Reitz and Embleton, 1984). Rootstock selection for mandarins seems to be more difficult than for major orange and grapefruit cultivars since each cultivar has its own peculiarities. Krezdorn(1977) stated that though Dancy Tangerines have adequate juice TSS, large fruit size and early legal maturity because of low TA, the season is shortened due to drying of the fruit on the tree and puffing of the peel. These effects are less marked on Sour orange and Cleopatra mandarin rootstock and there seems a preference for the taste of the fruit grown on these rootstocks. Fallahi and Rodney (1992) observed that fruit of Fairchild mandarin on Carrizo citrange had the highest soluble solids concentration while those on Volkamer lemon and rough lemon had the lowest soluble solids and total acids.

It is now widely recognised that *Poncirus trifoliata* is a rootstock that gives good orange quality, particularly in marginally cool citrus growing areas of the world (Reuther, 1969; Sale, 1983). In New Zealand, regardless of the influence of season or district, there was marked and consistent superiority in the composition and quality of oranges produced by trees on *P. trifoliata* rootstock compared to sweet orange and rough lemon (citronelle) (Fletcher and Hollies, 1965) and Troyer and mandarin rootstock (Brown, 1985). Oranges on trifoliata rootstock had slower tree growth and yields per tree were reduced approximately in proportion to tree size. Fruit quality was better on *trifoliata* rootstock, particularly with high sugar levels and better flavour. Skins were of medium thickness, with the other rootstocks often having thicker skins.

2.1.5 Nutrient status of the tree

Citrus responds readily to nitrogen applications almost everywhere and to potassium application on acid sands,but slowly to potassium on alkaline or fine textured soils. Phosphorus has seldom been found lacking in soils planted to citrus. Therefore growers focus mainly on manipulation of nitrogen and potassium (Reitz and Embleton, 1984). High levels of nitrogen in oranges are associated with thicker peel, lower percentage of juice, coarser peel texture and greener fruit colour. Studies on oranges in Florida have shown that increasing rates of nitrogen fertilization delays commercial maturity by increasing soluble solids content and increasing acidity thus decreasing the brix:acid ratio. Koo and McCornak (1995) found that high nitrogen fertilization of Tangerines increased acidity and delayed maturity. Similar results of increased acidity of fruit with heavy nitrogen fertilization was found by Bouma

(1961) in Australia.

Increasing potassium strongly increases acidity of the juice in grapefruit thus reducing the TSS:TA ratio and delaying maturity (Embleton et al., 1956; Smith and Rasmussen, 1960). Fruit with potassium deficiency have coarse and thick but well-coloured rind, hollow cores, and high TA in the juice and the correction of an actual deficiency will reverse these characteristics (Reitz and Embleton, 1984). Potassium applications have produced inconsistent results on most quality factors although Yuda et al. (1981) reported a substantially increased TSS:TA ratio.

2.1.6 Chemical sprays / growth regulators

Lead and calcium arsenate were used on a commercial basis to reduce juice acidity and advance maturity of oranges and grapefruit until arsenic was banned from use in citrus in the United States of America. A synthetic organic arsenical, arsonic acid or P-G which is considered to have much lower toxicity has reduced acidity of Florida grapefruit as effectively as lead arsenate (Wilson, 1988). Inconsistent effects on internal quality of grapefruit have been observed following the use of Gibberellic acid, 2,4-D and their combination (Davies, 1986). Sandhu (1992) measured little effect of Gibberellin acids on TSS and acid when sprayed preharvest on Kinnow mandarin. In Israel a combination of 18-20ppm 2,4-D plus 5% potassium nitrate is recommended for most cultivars to increase citrus fruit size except for early harvest cultivars as potassium nitrate increases juice acidity (Erner et al., 1993).

2.1.7 Storage conditions

Although storage temperature is of prime importance for overall storage quality of fruit, the response of citrus fruits to temperature is much less dramatic than that of climacteric fruit such as apples and bananas (Baile,1961). Too cold a temperature leads to chilling injury whereas too high a temperature during storage favours fungal decay, rapid water loss and increased softening. The rate of postharvest respiration of citrus fruit is low and is directly proportional to temperature in the range of 10°C

- 35°C (Grierson and Ben-Yehoshua, 1984). Cohen et al., (1985) in 'Murcot' mandarin found that storage temperature of 13°C enhanced senescence and impaired fruit quality compared to lower temperatures of 8, 5 and 2°C during three weeks storage and one week shelf life at 17°C.

The response of citrus cultivars differs during different storage temperatures. A progressive decline in acidity in Satsuma fruit during cool storage at 5°C for four weeks and a further one week at ambient temperature and in 'Nova' tangerine held in cool storage at 2 or 5°C followed by one week at 17°C to eight or 12 weeks were measured by Harty and Sutton (1990) and Cohen et al., (1991) respectively. Thus it seems that Satsuma cultivars could be successfully stored at temperatures between 5°C and 10°C at high relative humidity of 80-95% for storage periods of eight to 12 weeks. Since fruit exported to Japan require 4 weeks shipment plus 1 to 2 weeks retail storage, there is future for quality fruit to be exported to Japan.

The practice of applying coatings to fruit and vegetables after harvest to reduce weight loss during storage is quite ancient. However Cohen et al (1985) reported that coating 'Murcot' mandarin fruits in the packing house with wax decreased the amount of juice , total soluble and acid content compared to non-waxed fruits.

2.3 Surface coating

Washing of citrus fruit following harvest is essential to remove dirt, insects, nutrient pesticide spray residues but also removes most of the natural wax from the fruit leading to undesirable side effects. Water loss through transpiration is greater in washed than in unwashed fruit leading to softness, dull appearance and increased susceptibility to infection. Washing increases fruit respiration rate resulting in increased physiological deterioration. Thus virtually all fresh citrus fruit are washed, treated with fungicide and a surface coating applied (Kaplan, 1986), despite the flavour degradation that often results (Ahmad and Khan, 1987; Ben-Yeshoshua, 1967; Cohen et al., 1990).

The coatings used for citrus are usually called 'waxes' since earliest citrus coatings were composed of waxes. This term has since been applied to all postharvest citrus coatings, although it is a misnomer as modern products commonly available contain little or no wax (Hall, 1981).

2.3.1 Types of coatings

Hall (1981) divided citrus waxes into three categories: solvent wax, water wax and paste / oil waxes. Solvent wax is based upon one or more resins of either a synthetic resin or the calcium salt of a natural wood rosin that had been previously hydrolysed with dimer acids dissolved in a petroleum solvent . Solvent waxes form a shiny, flexible film on the surface of fruit (Hall, 1981;).

Water waxes are of two types:
(1) Resin solution composed of a solution of one or more of several alkali soluble resins or resin like materials such as shellac, protein, natural gums, tall oil or wood rosins.
(2) Emulsion waxes are composed of a natural wax such as carnauba, paraffin or a synthetic coating such as oxidised polyethylene emulsified in a soap or a detergent. Polyethylene coatings have the advantage of allowing the coated fruit to respire, thus avoiding the flavour changes that occur with less permeable coatings (Davis and Hoffmann, 1973). As a result a number of polyethylene based coatings have been developed to improve storage life of fruit (Ben-Yehoshua, 1969; Hall, 1981;). Davis and Harding (1960) reported the reduction of rind breakdown of grapefruit by an orchard spray of polyethylene emulsion. Gassener et al., (1964) (cited by Ishida, 1994) developed a polyethylene wax emulsion called 'Tag' for use as a skin coating for fruits. Its major effects were the reduction of weight loss by up to 60% (at the sixth day after treatment at 21-23°C, 60-75% RH) and inhibition of shrinkage. 'Tag' also significantly extended storage life of coated fruit by delaying other physiological aspects of deterioration (Ben-Yehoshua, 1967). Interestingly, 'Tag' coated oranges showed about 1.8 times as much resistance to O_2 diffusion as to CO_2 diffusion,

whereas the resistance to O_2 and CO_2 diffusion in uncoated fruit are equal (Ben-Yehoshua, 1967).

Hagenmaier and Shaw (1991, 1992) stated that resinous coatings have two different properties compared to waxy coatings that tend to inhibit air exchange: first, resinous coatings are more effective at sealing holes in the fruit epidermis; second they have lower permeability to gases.

Paste / Oil Waxes are mainly composed of paraffins of various melting points blended to give the desired viscosity.

In New Zealand 'Citrus Gleam'(shellac), 'Citruseal'(polyethylene) and carnauba coatings are being used in the citrus industry although their effects on satsuma mandarin are not documented.

2.4 Effects of coatings

The application of coatings has been practised by the fruit and vegetable industries for the past five decades for rendering the products more glossy and attractive in appearance and of reducing shrinkage and water loss. The appearance of fruit at the marketplace is often the main quality that affects the price paid (Ben-Yehoshua, 1967; Hall, 1981; Trout et al., 1942). Assessing the performance of coatings on fruits has led to the discovery that coatings also modify their internal atmosphere, reduce respiration, delay ripening and produce off flavours (Banks, 1984; Ben-Yehoshua, 1967; Eaks and Ludi, 1960; Kwak et al., 1992, Hagenmaier and Baker, 1993; Puvris, 1983).

2.4.1 Weight loss

Weight loss through transpiration is a major factor in the postharvest deterioration of citrus fruit. Transpiration causes desiccation, shrivelling, accelerated softening, loss of attractive appearance of the fruit and accelerates senescence (Ben-Yehoshua 1969; Ben-Yehoshua and Shapiro 1981). Weight loss also causes loss of saleable weight and thus is a direct loss in marketing (Woods, 1990).

Weight loss as low as five percent renders oranges unsaleable (Kaufmann et al., 1956; Grierson and Wardowski, 1978). In citrus loss of weight is mainly due to loss of water from the peel not the pulp. Ben-Yehoshua (1969) reported that after two months' storage at 20°C in 50- 75% relative humidity, the peel of 'Valencia' oranges lost 9.5% of its weight whereas the pulp lost only 2.1%. Since the peel is a visible marketing feature, changes in the appearance of the peel will have adverse effect on the marketability of the fruits. Fruit coatings block or slow moisture migration into the surrounding air, reducing moisture loss.

2.4.2 Modified atmosphere

The peel or skin of a fruit constitutes an important barrier to gas diffusion and hence influences the internal atmosphere composition. For instance, Burg and Burg (1965) observed that internal CO_2 and C_2H_4 (ethylene) concentrations in apples declined considerably when the fruit skin was peeled off. Ben-Yehoshua (1965) suggested that the flavedo portion of the orange fruit is the primary site of resistance to CO_2 and O_2 diffusion in oranges. A five fold increase in diffusion resistance during 60 days storage of oranges due to the drying of the peel was shown by Ben-Yehoshua (1969).

Coatings reduce the gas exchange between fruit and atmosphere resulting in reduced respiration rate, elevated internal CO_2 concentration, reduced internal O_2 and altered C_2H_4 concentration (Hagenmaier and Baker, 1993; Smith et al., 1987). The degree to which these factors are altered for a given commodity depends on species, cultivar, mass : surface area ratio and respiration rate (Smith et al., 1987). Ladeinde and Hicks

(1988) observed that paraffin wax applied to the root plate of onions caused a dramatic reduction in internal O_2 and elevation of internal CO_2 concentration. Burg and Burg (1965) reported that when the pedicels of tomatoes and green peppers were blocked with lanolin paste, CO_2 emanation was retarded by about 60% with cantaloupes and 10% in grapefruit and respiration and ripening retarded. No change occurred with oranges, lemons, apples, avocados, limes, pumpkins, bananas, pears, plums or acorn squash. Ben-Yehoshua (1967) observed slightly higher CO_2 and markedly lower O_2 concentrations in internal atmosphere as well as lower respiration rate in oranges, avocados and bananas coated with 'Tag'. Hagenmaier and Baker (1993) reported that fruit with shellac and resin coatings applied as a single layer or as a second layer had a markedly higher ratio of CO_2 to O_2 than fruit not coated or coated only with wax microemulsion.

Reduced gas exchange of coated citrus fruit may be accounted for in two different ways: the coating forms an additional barrier through which the gas must permeate, or the coating plugs openings in the peel. The mechanism operating depends on what is the main pathway for gas exchange in uncoated fruit (Banks et al,. 1993; Hagenmaier and Baker, 1993).

2.4.3 Respiration

Respiration a major metabolic process basic to all living plant tissues is described as the oxidative breakdown of complex materials (starch, sugars and organic acids) present in cells to simpler molecules such as CO_2 and H_2O, with the concurrent production of energy and other molecules which can be used by the cell for synthetic reaction (Wills et al., 1989). Oxygen is used and CO_2 is produced by this process with a release of energy in the form of adenosine triphosphate (ATP) which is essential for maintenance of cellular organisation, membrane integrity of living cells and to transport metabolites. The respiration rate of produce is an excellent indicator of the metabolic activity of the tissue and thus is a useful guide to the potential storage life of the produce. The storage life of the commodity is generally inversely proportional to its respiration rate (Kader, 1985; Wills et al., 1989). The respiration process in plant tissue can take place in presence (aerobic) or the absence of O_2 (anaerobic respiration sometimes called fermentation) (Wills et al., 1989).

Aerobic respiration

Most of the energy required for maintaining the cellular organisation of tissue is supplied by aerobic respiration. The respiration of substrates involves three metabolic pathways:

1. Glycolysis which is a degradative pathway whereby D-glucose is oxidised to pyruvate. Glycolysis is accompanied by the formation of ATP, although this is only about a quarter of the ATP that can be derived from the complete oxidation of glucose to CO_2 and water. Glycolysis can proceed either under aerobic or anaerobic (hypoxic) conditions (Montgomery et al., 1990).
2. Citric acid cycle: The net effect of the cycle is the oxidation of acetic acid (Acetyl CoA) to CO_2 and water.

3. Electron transport system, the phase of respiration where low-energy nicotinamide adenine dinucleotide (NAD) is reduced to the high energy NADH. Electrons are transferred by a series of intermediate compounds to combine with O_2 to form H_2O and produce ATP (Montgomery et al., 1990).

Anaerobic respiration

The amount of O_2 available in plant tissue is unlimited under normal atmospheric conditions (20.95% O_2). However, under various storage conditions of low levels of O_2 and high CO_2, the amount of O_2 may be limited and insufficient to maintain complete aerobic metabolism in plant tissues (Wills et al., 1989). Under these conditions the tissue can initiate anaerobic respiration by which glucose is converted to pyruvate but pyruvate is no longer oxidised to citrate. It is instead decarboxylated to either lactic acid (animals) or acetaldehyde and ethanol in plants (Fig 2) (Wills et al., 1989). This results in development of off flavour and tissue breakdown. The O_2

concentration at which anaerobic respiration occurs depends on several factors such as species, cultivar, maturity, respiration rate of commodity, gas diffusion characteristics of tissues and temperature (Kader, 1986; Wills et al., 1989). Anaerobic respiration produces much less energy per mole of glucose than aerobic respiration, but it does allow some energy to be made available to the tissue under adverse conditions (Wills et al., 1989).

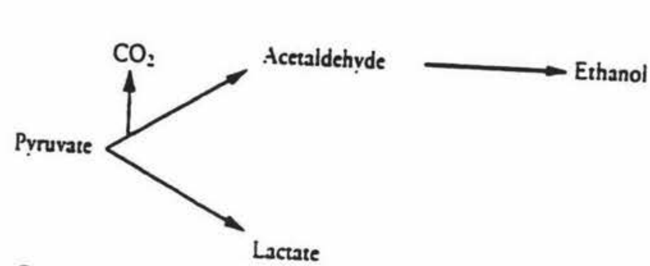


Figure 2 Pathwys of anaerobic metabolism (Wills et al., 1989)

2.4.4 Off flavours

Off-flavour in fruits results from anaerobic respiration where pyruvate is decarboxylated to form ethanol and acetaldehyde (Wills et al., 1989). Davis (1971) found the ethanol content of juice of stored citrus fruit was influenced by modified atmospheres and waxing. The ethanol content of juice of 'Temple' and 'Valencia' oranges and grapefruit increased with decreasing oxygen concentration, and the waxed fruit usually contained higher levels of ethanol than did nonwaxed. Kwak et al., (1992) reported that fruit decay and off-taste of juice of satsuma mandarin developed rapidly at temperatures 1, 8 and 20°C in polyethylene bags containing 100% CO_2 during storage. Off-odour developed more slowly and occurred after 15 days in fruits kept in perforated bags at 20°C, or after one month at 1O°C.

2.4.5 Appearance

Fresh citrus fruit is coated primarily to give gloss to the surface, thus improving market appeal, with weight loss reduction a secondary goal (Kaplan, 1986; Hall, 1981). However Hagenmaier and Baker (1993, 1994, 1995) have shown that weight loss and gloss are related eg. low weight loss helps to preserve gloss. Both can be achieved with layered coatings, the first of which is a wax microemulsion and the second coating can either be a wax selected for gloss or a higher gloss shellac or resin coating. Hagenmaier and Baker (1994) found the gloss of oranges and grapefruit coated with wax was higher than that of uncoated fruit but lower than that of fruit coated with high gloss commercial coating of resin and shellac.

2.5 Thickness of coating

Vines et al., (1968) observed that thicker than normal waxing did not appreciably affect external manifestations of gas exchange but internal CO_2 increased and internal O_2 decreased in relation to thickness of applied wax. Ben- Yehoshua (1967) and Davis and Hofmann (1973) found weight loss decreased with each additional coating up to only three coatings. Multiple coatings did not further reduce weight loss but increased the ethanol content and resulted in off-flavours resembling those of fruit in anaerobic atmospheres. The thickness of the coating also markedly reduced the internal O_2 content. Hagenmaier and Baker (1993) found shellac coated grapefruit had 4 times as high CO_2 resistance as polyethylene wax. They concluded that for CO_2 exchange, coating type is more important than thickness whereas for resistance to water vapour coating thickness is as important as type of wax.

CHAPTER 3 MATERIALS AND METHODS

Introduction

Fruit of the Satsuma mandarin (*Citrus unshiu* Marc.) cultivars 'Silverhill' and 'Miyagawa' from selected orchards in the main citrus growing districts of New Zealand were obtained in 1994. Fruit of 'Silverhill' from one Kerikeri orchard was used in 1995. All fruit were sent to Massey University where the experiments were carried out. Fruit quality assessments were made immediately on receipt and after cold storage at 6^0C or 9^0C. Fruit were either coated or left untreated before storage. In 1994, a trained sensory panel evaluated fruit quality after storage, whereas in 1995 an untrained sensory panel was used.

3.1 Cultivars

Fruit of cultivars Silverhill (a mid season cultivar) and Miyagawa (an early season cultivar) grown on trifoliata (*Poncirus trifoliata* (L) Raf.) rootstock were selected for the experiment in 1994 and 'Silverhill' in 1995.

3.2 District

Fruit of each cultivar was obtained from one orchard in each of the citrus growing districts of Kerikeri, Gisborne and Bay of Plenty in the North Island of New Zealand (Table 1).

1994 Experiments

3.3 Fruit harvesting

There were 4 or 5 harvests over the picking season for each cultivar. The fruit samples were picked randomly from trees within the same orchard block or taken from several bins filled in a commercial pick in 1994. The fruit were the more mature ones if picked before commercial maturity (TSS:TA 7:1), otherwise typical of fruit harvested for marketing at the later dates. The selected fruit were packed into ventilated cardboard citrus cartons and forwarded to Massey University by courier where they were received within two days of harvest.

Table 3. Citrus harvest dates (day and month) by cultivar, district and grower (1994).

	Grower	Pick1	Pick2	Pick3	Pick4	Pick5
'Miyagawa'						
Kerikeri	1	21/4	6/5*	12/5	9/6	-
Bay of Plenty	2	24/5	24/6	5/7	14/7	-
Gisborne	3	10/5	20/5	8/6	28/6	20/7*
'Silverhill'						
Kerikeri	4	28/4	11/5*	20/5	17/6	20/7*
Bay of Plenty	5	3/5	1/6	21/6	13/7	20/7
Gisborne	3	20/5	8/6	28/6	20/7	-

* Fruit from these harvests were used in storage trial.

3.4 Fruit analysis at harvest

In the laboratory the required total number of fruit was selected, based on absence of punctures, low skin blemish and similar size and colour. At each harvest a subsample of 21-29 fruit were selected from each line of fruit. Skin colour was measured at two opposite positions on the equator of each fruit. The fruit were randomly divided into seven to nine subsamples (replications) each of three fruits.

The fruit were halved, the juice squeezed using a hand juicier and filtered through a sieve (10 holes per cm^2) before measuring the Total Soluble Solids and titratable acid of each bulked juice sample.

3.4.1 Fruit weight

In the laboratory , 21 - 27 fruit were individually labelled and weighed on a Mettler electronic balance to one decimal place at harvest, out of cold storage and prior to final analysis.

3.4.2 Colour

Colour measurements (H ND L values) were made on each labelled fruit with a Minolta DP100 portable chromameter. The meter was calibrated at illuminant condition C(6774°k) with a green standard. The mean L and H value for each fruit was used for statistical analysis.

3.4.3 Acidity

A 1 ml aliquot of juice per subsample of three fruit was mixed with 30 ml distilled water in a 100 ml plastic container. Using a Mettler DL21 automatic titrator, it was titrated with 0.1 N sodium hydroxide to an end point of pH 8.2. The volume of alkali required was multiplied by a factor of 0.064 to calculate the juice titratable acidity expressed as percentage citric acid.

3.4.4 Total soluble solids

A hand held temperature compensating Atago N20 refractometer was used to measure the total soluble solids of juice. The refractometer was zeroed using distilled water at the start of each sample. One or two drops of extracted juice was put on the prism and the reading recorded. The prism surface and the light plate were thoroughly washed with distilled water and dried with a clear soft tissue paper between each reading.

3.5 Effect of skin coating during cold storage

Mandarin fruit from the second and fifth pick of 'Silverhill', and second pick 'Miyagawa' from Kerikeri and fifth pick from Gisborne were used in the storage experiment (Table 1). The fruit were divided into groups of 21 - 27, individually labelled, weighed and skin colour measured. Groups of fruit were then allocated for treatment with wax or no wax and held in cold storage for 3, 5, or 7 weeks.

Fruit from the second pick (early May) were coated with 'Citrus Gleam' (shallec) obtained from Castle Chemicals, Australia) by individually dipping once and drying on a rack at room temperature for 3 hours before packing in citrus cartons for storage.

'Citruseal' (polyethylene wax), obtained from Milestone Chemicals, Australia was used to coat fruit from the fifth pick. 'Citruseal' was mixed with water in the ratio of 1:2, and the fruit dipped once and dried at room temperature for 3 hours before packing in citrus cartons and storage. Fruit from the second pick were stored at 6^0C. Fruit from the fifth pick were stored at either 6^0C or at 9^0C. The store relative humidity was 60%. After cold storage fruit was held at 20^0C for seven days before observation. A further 20-25 fruit per treatment were stored and used for sensory evaluation.

3.6 Sensory evaluation

At harvest and after each storage period (cold storage + 1 week at 20°C), 18 - 25 fruit (rotted fruit discarded) from each treatment were subjected to sensory evaluation. Juice of 'Silverhill' and 'Miyagawa' at the 2nd harvest was extracted and the bulked juice of each cultivar divided into 350 ml subsamples, frozen in 350 ml plastic containers and held at -16^{0}C. This juice was thawed as required and used as the baseline reference sample for each sensory evaluation.

Eight volunteer panellists of staff and students of Massey University were trained for the mandarin sensory panel. Training began on 4th May in the Food Technology Sensory Laboratory where the panellists were introduced to tasting practices and given opportunity to show they were able to recognise basic differences in the level of acidity, sweetness and bitterness by tasting citric acid (0.25, 1.25%), sucrose (2.5, 10%) and caffeine (0.05%) respectively (Jellinek, 1985). On 11 May at the panel's second training, juice of 'Miyagawa' and 'Silverhill' was used to practice the method of scoring juice samples as planned for this study to establish the standard test procedures and discuss standardisation of sample scores. This was done using three samples of 'Silverhill' juice. To one sample sucrose was added to give a TSS: acid ratio 10.9:1 (sweetest sample). Sucrose was added to a second sample to a TSS:acid ratio 8:1 of medium sweetness and the third sample was the reference sample (initial juice) with the lowest TSS:acid ratio (6:1). The rating of 'Silverhill' and 'Miyagawa' reference samples were standardised among the individual panellists by scoring individually and then collectively agreeing a standard score for each of the reference samples (Appendix 11 and 111).

At each day of sensory evaluation, one sample of the reference juice was thawed by removing it from the freezer about 10 hours before tasting and placing in room temperature of 15 to 17^{0}C. For sensory evaluation the bulked juice from experimental fruit was divided into 50ml samples. The samples were coded and given to panellists in randomised order. Each sample was rated for sweetness, acidity and mandarin flavour on a scale of 0 (very low) to 6 (very high). To maintain consistency between dates the reference sample of known score in each category was available as a standard at each time of evaluation. An eight member panel evaluated each juice sample ranging from 1 to 8 at 11am using an evaluation form (Appendix 11). Each member of the panel followed the procedure as detailed in the liquid evaluation sheet (Appendix 1V).

3.7 1995 Experiments

3.7.1 Effects of waxes on fruit quality through the cool storage period

Mandarin fruit of cultivar Silverhill were obtained from a Kerikeri orchard (John Willets) on 13th June, 1995. The fruit were wiped gently with a cotton cloth to remove pesticide residue. Twelve fruit were randomly selected and allocated into six subsamples (replications) each of two fruits.

Fresh weight and colour were measured (as in 1994). The two fruit per subsample were halved, juice squeezed and sieved before measurement of the TSS and acid concentration of each subsample. The remaining fruit were sorted and randomly divided into subsamples of 12 (experimental) and 15 (sensory) fruit for each of four treatments,labelled and weighed.

A gas sampling vial was fixed with araldite glue to each of 12 experimental fruit at its equator. This consisted of a 1ml glass vial from which the bottom had been removed and the top fitted with a 0.4ml glass tube with rubber septum. The fruit were left at room temperature for 24 hours for the araldite to dry. Each subsample of 27 fruit was allocated to one of four coating treatments:

1. control (no coating),
2. polyethylene wax ('Citruseal'mixed in water at a ratio of 1:2).
3. a shellac - based coating (undiluted 'Citrus Gleam')
4. Carnauba wax (supplied by a commercial packhouse).

An individual fruit was dipped for 5 seconds into its respective treatment and allowed to dry on a rack for three hours. Weight and colour measurements were taken of individual fruit allocated for sensory evaluation. All fruit were stored in citrus cartons at 6°C. After 24 hours at 6°C a preliminary study investigated the time taken for a fruit's internal gases to equilibrate with the sampling chambers. Each experimental fruit vial was flushed by removing the septum and injecting cool air (6°C) and replacing the rubber septum. The glass vial above the rubber septum was filled with water to prevent atmospheric contamination of samples as the sampling needle was withdrawn. At 6°C a 90µl gas sample was taken from each chamber at 1, 9, 24, 51, 75 and 133 hours after sealing, and O_2 and CO_2 concentration measured.

A sample of the gas mixture in the sampling chamber attached to each fruit was withdrawn by inserting a hypodermic needle fitted to 5.0 ml syringe through the septum. The septums were replaced after 133 hours. A 90µl sample of gas from the underneath the skin of fruit was injected into a stream of oxygen free nitrogen (flow rate 32 cm^3/min). The gas passed through an oxygen sensor (City Technology oxygen sensor - c/s type Citicell) in series with an Infra Red Gas analyzer (Model No WA 470E-001-2500-1). The signals from the sensors were integrated with Hewlett Packard HP3394A integrators. The $C0_2$ samples were compared with 2.02% CO_2 standards (NZIG certified gas standard) and 0_2 with dry air (20.95% 0_2).

The percentage O_2 and CO_2 values were converted to the gas partial pressure (KPa) by multiplying by the atmospheric pressure of the day and dividing by 100.

Oxygen and carbon dioxide from the vials of each experimental fruit were measured (as above) on 28th June (2 weeks cold storage), 13th July (4 weeks cold storage), 27th July (6 weeks cold storage) and after 6 weeks storage plus 7 days storage at 20°C (3rd August). The 12 experimental fruit in each treatment were divided into 6 subsamples, juiced and TSS and acidity measured for each subsample on 3rd August (Section 3.4.3 and 3.4.4 respectively). At 6 weeks storage at 6°C and again at 20°C after one week, fruit from each treatment were allocated into 2 fruit per replication. 10ml of extracted juice from each treatment was used to measure the headspace volatiles. The 10ml sample of juice per replication was transferred into a 50ml

Erlenmeyer flask which was then sealed with suba seal and equilibrated in a water bath at 30°C for 30 minutes. A 100μl of gas was removed from each flask using a 1ml monoject tuberculin syringe fitted with a 25 gauge 15mm length needle and injected into a Pye Unicam gas chromatograph fitted with a flame ionisation detector. The operating conditions of the gas chromatograph were injector temperature 100°C, detector temperature 180°C, column temperature 40°C, flow rate of nitrogen was 30ml/min, hydrogen 30ml/min and air 300ml/min. The column was a 10% Carbowax 20M 80/100 mesh 2.2m long by 1/8 inch diameter. Results were collected using a Rikadenki model B281HS chart recorder.

Fruit in each treatment for sensory evaluation were weighed out of the cold storage at the same dates. The colour of the sensory fruit was measured before the juice was extracted and presented to an untrained sensory panel for evaluation. Five staff and students of Massey University evaluated the juice using a hedonic scale method (Appendix V).

3.7.2 Effects of wax application methods on mandarin internal atmosphere and eating quality

Fruit of cultivar Silverhill were picked on a Kerikeri orchard on 23rd May 1995. The fruit were gently wiped with muslin cloth to remove soiling. Twelve fruit were randomly allocated to 6 subsamples of 2 fruit and juice TSS and acid measured as in experiment 1. Remaining fruit were sorted into subsamples of 12 (experimental) and 5 (sensory) fruit in each of seven treatments, and labelled individually. A 1ml glass sampling vial was attached to each experimental fruit as in experiment 1. After 24 hours each subsample of 17 fruit was allocated to one of the seven surface coating treatments:

1. control (no coating)
2. shellac / 'Citrus Gleam' - undiluted (1 dip)
3. shellac / 'Citrus Gleam' - undiluted (dip, dry, dip)
4. shellac / 'Citrus Gleam' - undiluted (brush)

5. * polyethylene / 'Citruseal'(1 dip)
6. * polyethylene / 'Citruseal' (dip, dry, dip)
7. * polyethylene / 'Citruseal' (brush)

   * mixed with water of ratio 1:2

Fruit in the one dip treatment was dipped once for about 5 seconds then allowed to dry on a rack at room temperature. Double dip fruit were dipped once, dried for 3 hours at room temperature and again dipped in the same material and dried. For treatments 4 and 7 a soft nylon hand brush was wetted in the coating and the fruit coated lightly by gently brushing the fruit.

Fruit were cool stored at 6°C and O_2 and CO_2 from the sampling chamber measured for each experimental fruit after 3 days (27 May) and 21 days (15 June). Fruit were then held at 20°C for 7 days (22 June) when chamber O_2 and CO_2 was measured (section 3.7.2) using a 50µl gas sample instead of the usual 90µl. Fruit fresh weight was again determined on 22 June. Juice from experimental fruit (2 fruit /replication) was extracted and acid and TSS measured on 22 June.

The fruit for sensory evaluation in each treatment were halved, juiced by hand juicer, sieved, bulked and given (50ml / treatment) to each of 5 untrained sensory panellists for evaluation.

3.7.3 Comparison of spray and dip application of 'Citrus Gleam'on 'Silverhill' mandarin.

A box of coated and uncoated 'Silverhill' fruit were obtained from a Gisborne packinghouse on 22nd June two days after picking. The former fruit had received the normal commercial fine spray application of wax followed by forced drying. Twelve uncoated fruit (2 fruit / replication) were randomly selected for immediate TSS and acid measurement. The rest of the fruit were allocated to the following treatments:

1. Spray -coated with 'Citrus Gleam'.
2. Dipped in 'Citrus Gleam' (for 5 seconds and dried 3 hours).
3. Uncoated Control.

Individual fruit (36 / treatment) in the experiment were weighed and placed into cool storage at 6°C. After 14 days (6 July), 18 fruit from each treatment were removed to 20°C for 6 days. On 12 July, those fruit were weighed and their internal O_2 and CO_2 measured by withdrawing a gas sample from each fruit by inserting a hypodermic needle fitted to a 5.0ml syringe into the core of fruit through the calyx end while immersed in water. A 90µl gas sample from each fruit was used to measure the gases as described in section 3.7.1.

The remaining fruit were removed to 20°C on 20 July (28 days storage) for 7 days. On 12 July and 27 July weight, TSS, acid and headspace volatiles were measured (sections 3.4.2, 3.4.3, 3.4.4. and 3.7.1. respectively) and sensory evaluation carried out on 50ml bulked juice samples (section 3.6.). On 27 July O2 and CO2 from the core of the fruit were measured before juice was extracted (section 3.7.1.)

3.8 Statistical analysis

Data for the different components were analysed without transformation by Analysis of Variance using the General Linear Model (GLM) product, a package program of the Statistical Analysis System (SAS Institute Inc., Cary, NC). Non parametric rank order analysis was carried on data of percentage weight loss, TSS:acid ratio and sensory scoring data.

CHAPTER 4 RESULTS

4.1 Maturation of mandarin cultivars grown in the three main citrus growing districts

Experimental fruit harvesting in Kerikeri began on 21 April and 28 April for cvs Miyagawa and Silverhill respectively. The commercial season lasted until 9 June for 'Miyagawa' and 20 July for 'Silverhill'. Harvesting of cvs Miyagawa and Silverhill started in Bay of Plenty on 24 May and 3 May compared with 10 and 20 May in Gisborne respectively (Table 3). Commercial harvesting finished on 20 July in both districts except cv Miyagawa finished one week earlier in Bay of Plenty.

4.2 Maturation of cultivars in Kerikeri

4.2.1 TSS

In cv Miyagawa the juice TSS percentage (ie. not corrected for acid level) of 10.39%, increased significantly to pick 2 (11.32%), then decreased significantly to pick 3 and remained the same at the final harvest (Fig 3A). In cv Silverhill the initial TSS was lower at 8.79% increased significantly to pick 2 then there was a downward trend through the subsequent harvests (Fig 3B).

4.2.2 Titratable acidity

The titratable acidity of the fruit showed a downward trend through the picking season in cvs Miyagawa and Silverhill. The acidity was significantly lower in pick 4 than other picks in cv Miyagawa (Fig 3A). The acidity decreased (0.15% and 0.2%) through the picking period in cvs Miyagawa and Silverhill respectively.

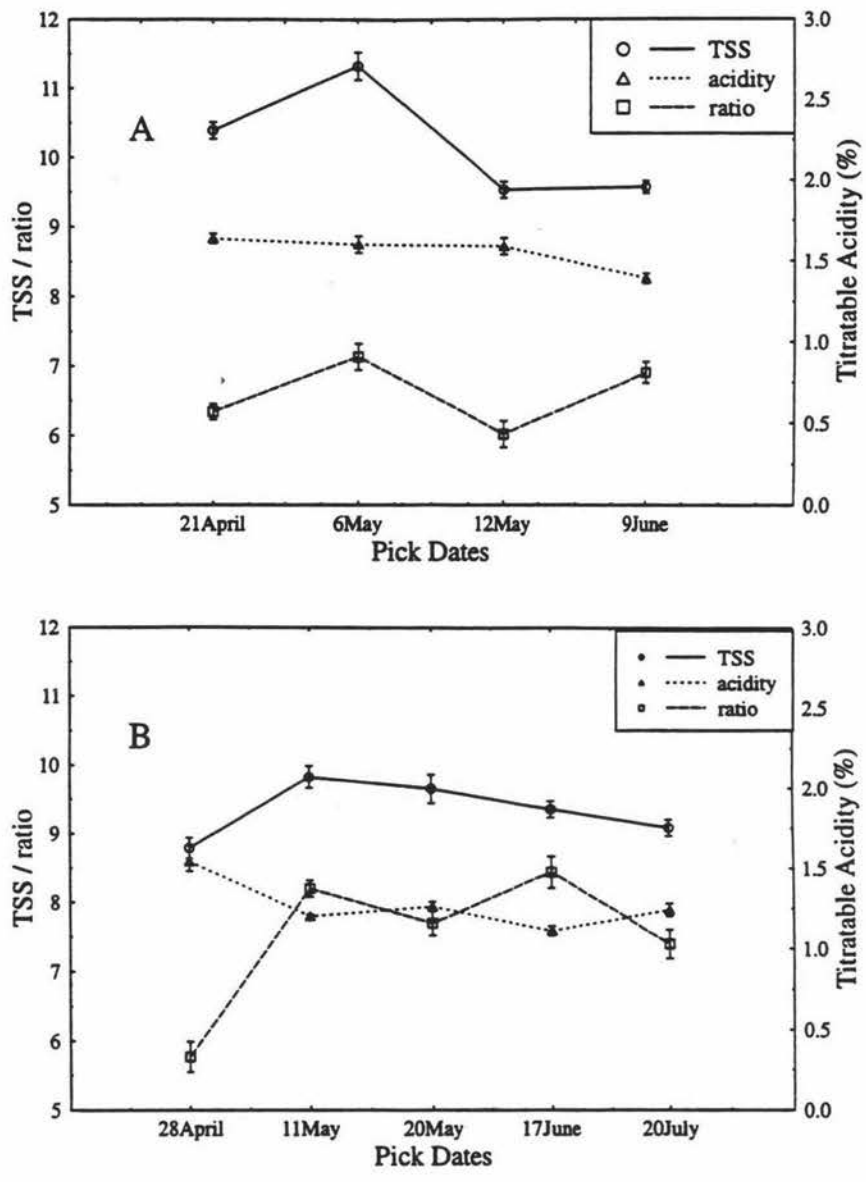


Figure 3 Seasonal changes in internal characteristics of 'Miyagawa' mandarin (A) and 'Silverhill' mandarin (B) at Kerikeri in 1994. Vertical bars represent standard error of the mean of 7 samples.

4.2.3 TSS : acid ratio

There were considerable fluctuations in the TSS:acid ratio and the maximum increase above that at the first pick was 0.78 from (6.34 to 7.12) and 2.67 (from 5.77 to 8.44) in cvs Miyagawa and Silverhill respectively (Fig 3A & B).

4.2.4 Fruit weight and colour

Fruit picked on 12 May were significantly smaller than fruit picked on other dates in cv Miyagawa while the third pick fruit were significantly heavier than in other picks in 'Silverhill' (Table 4). While fruit were usually of similar weight for a cultivar, 'Silverhill' fruit tended to be a little smaller than 'Miyagawa'.

The mean H value in both cultivars showed a downward trend decreasing from 71.37 to 68.89 in 'Miyagawa' and 99.07 to 68.76 in cv Silverhill. The L value fluctuated around 69 and 67 in cvs Miyagawa and Silverhill respectively (Table 4), the biggest change occurring between the first two picks of 'Silverhill'.

4.3 Fruit maturation in the Bay of Plenty

4.3.1 TSS

The TSS in cv Miyagawa increased significantly from 7.63 to 8.4 between the first two picks but decreased to 8.09 in the 4th pick (Fig 4A). 'Silverhill' TSS was about 9% but was lower at the 2nd and 3rd harvests (Fig 4B).

4.3.2 Titratable acidity

The percentage acidity in fruit of both cultivars declined significantly through to the early July pick and then remained constant . The acidity decreased 18.6% in

'Miyagawa' and 24.7% in 'Silverhill' over the 8 - 11 week picking period but was always much higher in 'Miyagawa'.

Table 4. Physical characteristics of mandarin cultivars at Kerikeri during the 1994 harvest.

Pick Date	Fruit weight(gm)	L Value	H Value
Miyagawa			
21 April	77.34a	69.73a	71.37a
6 May	76.81a	68.69b	67.63c
12 May	66.92b	69.79a	69.03b
9 June	80.34a	69.81a	68.89b
Silverhill			
28 April	62.25b	58.18c	99.07a
11 May	62.75b	67.53ab	74.71b
20 May	70.21a	67.46ab	71.86c
17 June	62.45b	66.85b	67.02d
20 July	63.16b	68.49a	68.76d

Within columns by cultivar, means followed by a common letter do not differ significantly at P = 0.05, according to Duncan's Multiple Range Test.

4.3.3 TSS: acid ratio

The ratio significantly increased (P = 0.05) from pick 1 (4.3) to pick 3 (5.95) and then remained similar in cv Miyagawa. In cv Silverhill picks 4 and 5 had a significantly higher ratio (7.86) than at all earlier harvest dates.

4.3.4 Fruit weight and colour

The mean fruit weight decreased slightly through the harvest period in cv Miyagawa (Table 5), but except for pick 4 showed little change through the picking dates in the slightly heavier cv Silverhill. Peel colour as reflected in change in H values suggested a similar decrease (fall in greenness) in both cultivars. There was a significant decrease in L value in 'Miyagawa' and a significant increase in 'Silverhill' (Table 5).

Table 5. Physical characteristics of cvs Miyagawa and Silverhill at Bay of Plenty in 1994.

Pick Date	Fruit weight	L value	H value
Miyagawa			
24 May	81.89a	70.28a	70.94a
24 June	77.58ab	68.48b	67.40b
5 July	71.67c	68.10b	66.22c
14 July	74.17bc	67.28c	66.38c
Silverhill			
3 May	79.44b	66.10a	74.81a
1 June	84.80ab	69.21b	68.70b
21 June	85.86ab	68.38b	68.05b
13 July	89.14a	67.09c	65.53c
20 July	82.10b	66.95c	66.14c

Within columns by cultivar, means followed by a common letter do not differ significantly at P = 0.05, according to Duncan's Multiple Range Test.

4.4 Maturation of mandarin cultivar at Gisborne

4.4.1 TSS

Picking date did not have a significant effect on TSS of either cultivar at Gisborne (Fig 5A and B). TSS ranged from 10.0 to 10.4% in 'Miyagawa' and 9.5 to 9.9% in 'Silverhill'.

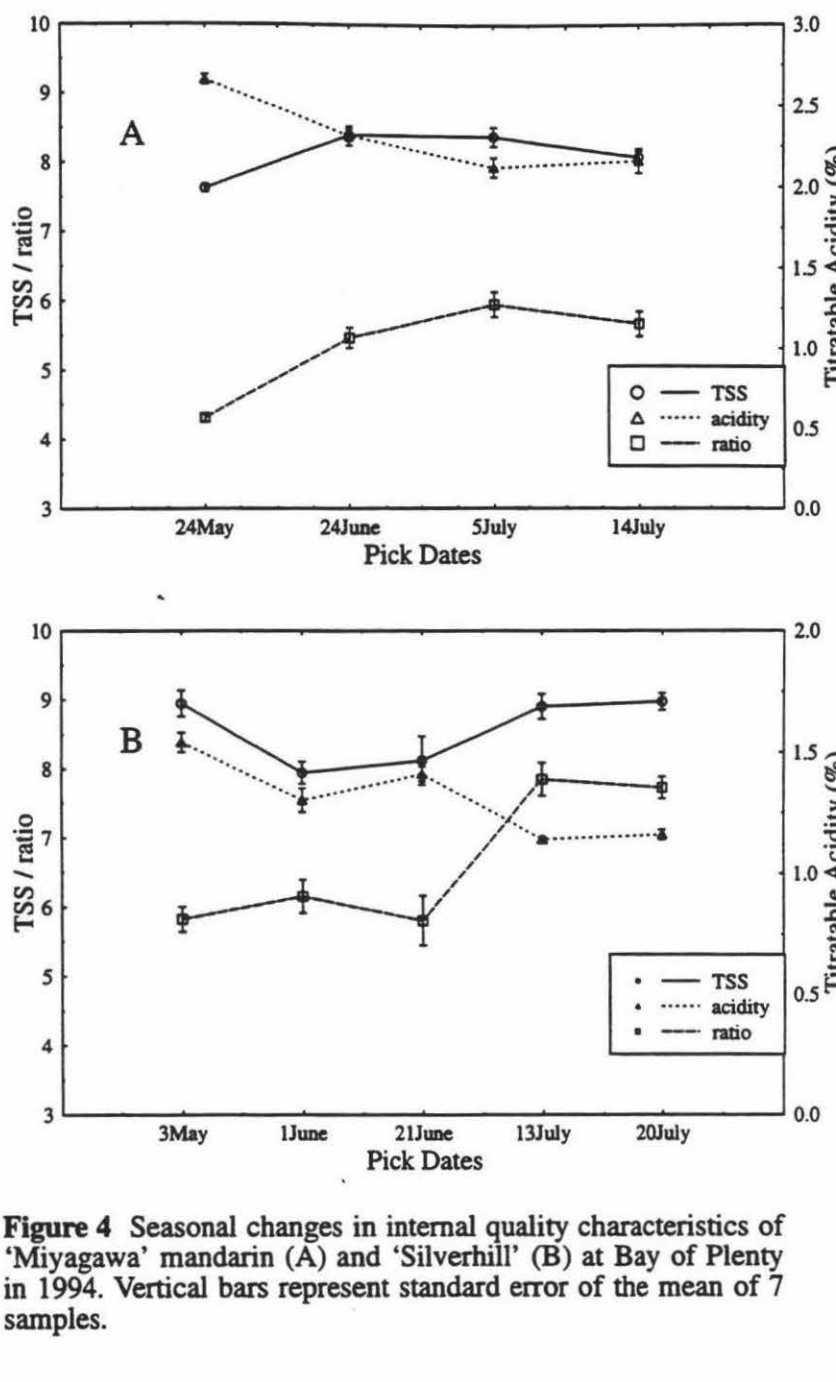


Figure 4 Seasonal changes in internal quality characteristics of 'Miyagawa' mandarin (A) and 'Silverhill' (B) at Bay of Plenty in 1994. Vertical bars represent standard error of the mean of 7 samples.

4.4.2 Titratable acidity

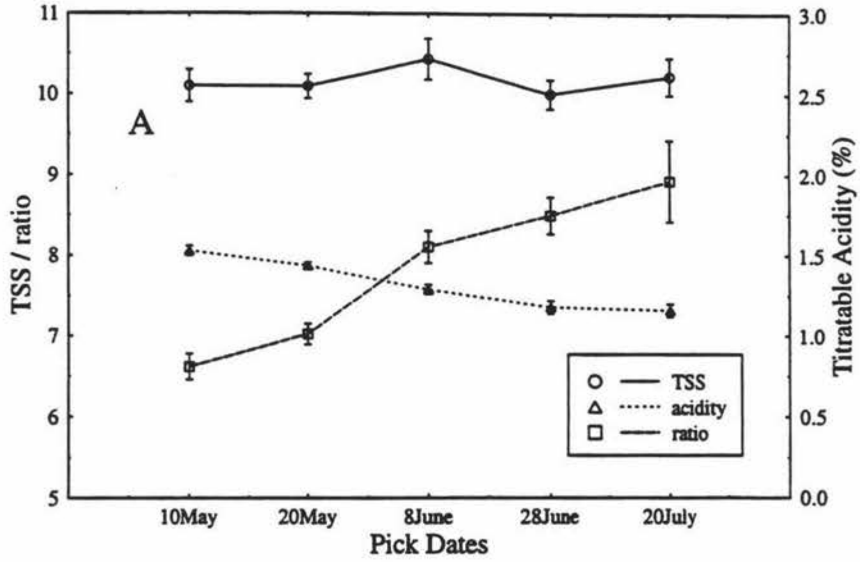
Acidity decreased steadily through the picking dates in both mandarin cultivars (Fig 5A & B). In cv Miyagawa acidity decreased from an initial 1.53% to 1.16% in picks 4 and 5 which was significantly lower than at earlier picks. In cv Silverhill acidity fell from 1.56% to 1.03% during the harvest period with highly significant differences between each of the picks.

4.4.3 TSS:acid ratio

The TSS:acid ratio increased as the season progressed, mainly due to reduction in the acid concentration in both mandarin cultivars. The first two picks had a significantly lower ratio than the last three picks in 'Miyagawa' as the ratio increased from 6.62 to 8.93 during the harvest period. In 'Silverhill' the ratio rose to a maximum of 9.5 in late July from 6.21 two months earlier with all harvest means significantly different (P = 0.05) from each other.

4.4.5 Fruit weight and colour

The weight of fruit from the 5th pick was significantly higher than fruit from earlier picks in cv Miyagawa. In cv Silverhill fruit from 4th and final harvest were significantly smaller than fruit from other picks (Table 6). The fruit L and H values decreased significantly through the picking dates in



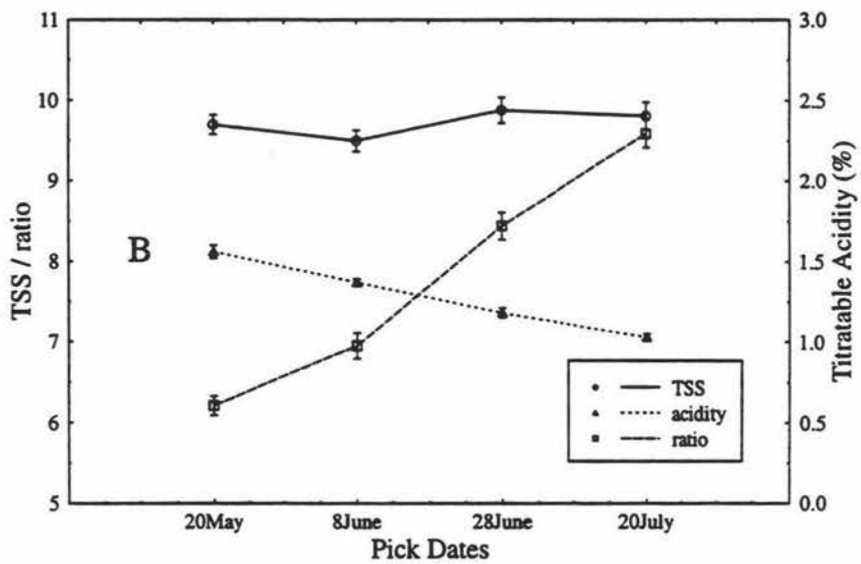


Figure 5 Seasonal changes in internal characteristics of 'Miyagawa' mandarin (A) and 'Silverhill' mandarin (B) at Gisborne in 1994. Vertical bars represent standard error of the mean of 7 samples.

'Miyagawa'. In 'Silverhill' the L value fluctuated through the harvest period while the H values decreased significantly as harvesting was delayed (Table 6).

Table 6. Physical characteristics of cvs Miyagawa and Silverhill at Gisborne in 1994.

Pick Date	Fruit weight(gm)	L Value	H Value
'Miyagawa'			
10 May	70.14b	71.45a	70.68a
20 May	69.63b	70.35b	69.22b
8 June	71.84b	69.87b	68.07c
28 June	76.31b	68.24c	67.63cd
20 July	87.01a	68.06c	66.87d
'Silverhill'			
20 May	74.35a	68.65ab	78.99a
8 June	70.92a	69.60a	69.48b
28 June	71.96a	68.27b	67.16c
20 July	62.58b	69.34a	67.50c

Within columns by cultivar, means followed by a common letter do not differ significantly at $P = 0.05$, according to Duncan's Multiple Range Test.

4.5 Effect of 'Citrus Gleam' coating and storage duration on fruit quality of early harvested Kerikeri mandarin (1994)

4.5.1 TSS

At harvest on 6 May and 11 May the juice TSS was 11.32% ('Miyagawa') and 9.83% ('Silverhill') respectively and showed only limited changes in 6°C cold storage plus one week at 20°C of 7 weeks (Tables 7a and b). 'Miyagawa' and 'Silverhill' fruit dipped in 'Citrus Gleam' had similar juice TSS as noncoated fruit.

4.5.2 Titratable acidity

Juice acidity decreased significantly during storage for the first five weeks and remained steady in cv Miyagawa across coated and noncoated fruit (Table 7a). Coated fruit had similar acidity at each storage period compared to noncoated fruit. In cv Silverhill (Table 7b) as storage period increased the acid concentration continued to fall, with a 14% decrease after 6 weeks at 6°C and 1 week at 20°C. The acidity in uncoated fruit was significantly higher than coated in 'Silverhill' fruit at each storage period though data at 3 weeks storage is shown (Table 7b).

Table 7a: Effect of storage period and 'Citrus Gleam' coating on internal quality of early harvested Kerikeri 'Miyagawa' mandarin (1994).

Storage Period	TSS (%)	Acidity (%)	Ratio
0 Days	11.32 ± 0.20#	1.59 ± 0.05a	7.12 ± 0.19c
3 Weeks^z	10.63 ± 0.17	1.33 ± 0.04b	8.18 ± 0.36b
5 Weeks	11.39 ± 0.15	1.18 ± 0.04c	9.80 ± 0.31a
7 Weeks	11.21 ± 0.15	1.22 ± 0.05bc	9.36 ± 0.34a
Significance	ns	***	***
7 weeks			
Uncoated	11.37 ± 0.13	1.17 ± 0.05	9.77 ± 0.41
Coated	11.06 ± 0.29	1.25 ± 0.09	8.96 ± 0.52
Significance	ns	ns	ns

Within columns of storage period (anova) and treatment (t-test), means followed by a common letter do not differ significantly at P = 0.05.
ns, ***, nonsignificant or significant at P = 0.001
± standard error of mean.
ratio analyzed using non parametric analysis.
z 3, 5, 7 weeks = 2, 4, 6 weeks at 6°C plus 1 week at 20°C respectively.

Table 7b: Effect of storage period and 'Citrus Gleam' coating on internal quality of early harvested Kerikeri 'Silverhill' mandarin (1994).

Period	TSS (%)	Acidity (%)	Ratio
0 Days	9.83 ± 0.16#	1.20 a	8.20 d
3 Weeks[z]	9.79 ± 0.17	1.04 b	9.41 c
5 Weeks	9.87 ± 0.12	0.99 b	9.96 b
7 Weeks	10.11 ± 0.16	0.93 c	10.90 a
Significance	ns	**	*
3 Weeks			
Uncoated	10.15a	1.10a	9.25 ± 0.19
Coated	9.43b	0.99b	9.56 ± 0.28
Significance	*	**	ns

Within columns of storage period (anova) and treatment (t-test) means followed by a common letter do not differ significantly.
ns, *, ** nonsignificant or significant at P = 0.05 or P = 0.01 respectively.
± standard error of mean.
ratio analyzed using non parametric analysis.
z 3, 5, 7 weeks = 2, 4, 6 weeks at 6°C plus 1 week at 20°C respectively.

4.5.3 TSS : acid ratio

The TSS to acid ratio increased significantly in cv Silverhill (8.20 to 10.90) during 7 weeks storage. In cv Miyagawa the TSS:acid ratio increased significantly during the first 5 weeks storage. Coating by 'Citrus Gleam' did not affect the TSS:acid ratio in either cultivar.

4.5.5 Fruit weight loss

Coating significantly lowered weight loss in both cultivars during 7 weeks cool storage (Table 8 and 9). In cv Silverhill weight loss was 7.5% in uncoated fruit compared to 5.7% coated in 'Silverhill' fruit. Weight loss almost doubled as storage period increased from 3 weeks to 7 weeks. Weight loss in 'Miyagawa' fruit was to lesser extent, 7.1% in uncoated fruit and 5% in coated fruit at 3 weeks storage.

Uncoated fruit tended to lose 2.7% and coated fruit 2% more weight at 7 weeks than at 3 weeks. A significant weight loss was measured as storage period increased in cv Silverhill. In cv Miyagawa the weight loss increased significantly only at 7 weeks storage.

Table 8. Effect of 'Citrus Gleam' coating and storage duration on weight loss in early harvested Kerikeri 'Miyagawa' mandarin (1994).

Storage Period	Percentage Weight Loss		
3 Weeks[z]	6.03b		
5 Weeks	5.58b		
7 Weeks	8.44a		
Significance	*		
Treatment	3 Weeks	5 Weeks	7 Weeks
Uncoated	7.13	6.55	9.77
Coated	4.99	4.79	6.96
Significance	***	***	***

Within columns of storage period (anova) and treatment (t-test), means followed by a common letter do not differ significantly.
*,*** significant at p = 0.05 and 0.001 respectively.
Non parametric analysis.
z 3, 5, 7 weeks = 2, 4, 6 weeks at 6°C plus 1 week at 20°C respectively.

Table 9. Effect of 'Citrus Gleam' coating and storage duration on weight loss in early harvested Kerikeri 'Silverhill' mandarin (1994).

Storage Period	Percentage Weight Loss		
3 Weeks[z]	6.64a		
5 Weeks	7.80b		
7 Weeks	12.44c		
Significance	*		
Treatment	3 Weeks	5 Weeks	7 Weeks
Uncoated	7.59a	8.68a	13.05a
Coated	5.68b	6.86b	11.80b
Significance	***	***	***

Within columns of storage period (Anova) and treatment (t-test), means followed by a common letter do not differ significantly.
*,*** significant at $p = 0.05$ and 0.001 respectively.
Non parametric analysis.
z 3, 5, 7 weeks = 2, 4, 6 weeks at 6°C plus 1 week at 20°C respectively.

4.5.6 Internal gas composition

Cultivar 'Silverhill' coated with 'Citrus Gleam' had significantly lower levels of oxygen and higher levels of carbon dioxide in core of fruit after 42 days storage at 6°C (Table 10a). The levels of both O_2 and CO_2 were similar when measured in uncoated fruit and fruit coated with polyethylene in both cultivars in storage for 42 days at 6°C (Table 10b).

Table 10a: Effect of 'Citrus Gleam' on internal (core) gas atmosphere composition of mandarin fruit after 42 days cool storage at 6°C.

Treatment	O_2 (KPa)	CO_2 (KPa)
'Miyagawa'		
Uncoated	14.47 ± 2.65	4.21 ± 0.58
Coated	7.4 ± 2.60	6.65 ± 1.05
Significance	ns	ns
'Silverhill'		
Uncoated	17.03a	3.42a
Coated	6.98b	7.34b
Significance	*	*

Within columns of cultivars, means followed by a common letter do not differ significantly at $P = 0.05$, according to t-test.
ns, * nonsignificant or significant at $P = 0.05$
± standard error of mean.

Table 10b: Effect of polyethylene coating on internal (core) gas atmosphere composition of mandarin fruit after 42 days cool storage at 6°C.

Treatment	O_2 (KPa)	CO_2 (KPa)
'Miyagawa'		
Uncoated	20.02 ± 0.13#	1.03 ± 0.08
Coated	19.68 ± 0.14	1.29 ± 0.11
Significance	ns	ns
'Silverhill'		
Uncoated	11.28 ± 2.18	6.05 ± 0.89
Coated	9.52 ± 2.31	6.72 ± 1.06
Significance	ns	ns

Within columns of cultivars, means followed by a common letter do not differ significantly at P = 0.05, according to t-test.
ns nonsignificant at P = 0.05.
± standard error of mean.

4.6 Effect of storage period, temperature and coating on internal quality of variety 'Silverhill' from late harvest (Kerikeri) in 1994

4.6.1 TSS

At harvest on 20 July the juice TSS was 9.09% and showed only limited changes during first 3 weeks (not significant) of 7 weeks storage. Temperature, coating and storage period did not have any significant effect on TSS of juice of 'Silverhill' (Table 11).

4.6.2 Titratable acidity (TA)

Temperature and storage period had a significant effect on TA. The TA decreased as storage period progressed, but there was no significant difference in acidity between 5 weeks and 7 weeks storage. Only after 7 weeks storage (6 weeks at 6°C and 1 week at 20°C) fruit at 9°C had significantly lower acidity than fruit at 6°C. There was no significant difference in juice acidity between coated and uncoated fruit (Table 11).

4.6.3 TSS:acid ratio

The TSS:TA ratio in fruits increased significantly during the 5 weeks storage period and remained similar at 7 weeks. Fruit stored at 9^0C had a higher ratio compared with fruit at 6^0C but was significantly higher at 7 weeks storage. TSS : Acid ratio in uncoated fruit was significantly higher than coated fruit only at 7 weeks storage (Table 11).

Table 11. Effect of storage period, temperature and polyethylene coating on internal quality of late harvest Kerikeri 'Silverhill' (1994).

Storage Period[y]	TSS (%)	Acidity (%)	Ratio
0 Days	9.09 ± 0.12#	1.24a	7.40c
3 Weeks[z]	9.53 ± 0.11	1.04b	9.38b
5 Weeks	9.51 ± 0.12	0.86c	11.40a
7 Weeks	9.58 ± 0.12	0.79c	12.48a
significance	ns	***	**
Temp(°C) (at 7 Weeks))			
6	9.59 ± 0.18	0.86	11.22
9	9.58 ± 0.16	0.71	13.72
significance	ns	***	***
Treatment (at 7 Weeks)			
Uncoated	9.79 ± 0.17	0.76 ± 0.03	13.09
Coated	9.38 ± 0.15	0.81 ± 0.04	11.85
Significance	ns	ns	*

Within columns of storage period (anova), temperature and treatment (t-test) means followed by a common letter do not differ significantly.
ns, *, **, *** nonsignificant or significant at P = 0.05, P = 0.01 and P = 0.001 respectively.
± standard error of mean
ratio analyzed using non parametric analysis.
z 3, 5, 7 weeks = 2, 4, 6 weeks at 6°C plus 1 week at 20°C respectively.
y data at 6 and 9°C included

4.6.4 Weight loss

Coated fruit had a highly significant lower weight loss compared with uncoated fruit at all observation dates. The weight loss in fruit increased as the storage period progressed rising from 9.57% to 15.72%. The weight loss in fruit stored at 6°C or 9°C was similar at each storage period (Table 12). Polyethylene coated fruit had a highly significant effect on weight loss compared to uncoated fruit at all storage periods. The difference in weight loss among coated and uncoated fruit increased from 2.6% at 3 weeks to 6.0% at 7 weeks storage (Table 12).

Table 12. Effect of temperature, storage period and polyethylene coating on percentage weight loss in cv Silverhill from late harvest in Kerikeri in 1994.

Storage Period[y]	Percentage Weight Loss		
3 Weeks[z]	9.57c		
5 Weeks	13.62b		
7 Weeks	15.72a		
Significance	***		
Temp(°C)	3 Weeks	5 Weeks	7 Weeks
6	9.64 ± .36	14.13 ± .56	16.53 ± .65
9	9.51 ± .30	13.08 ± .59	14.64 ± .59
Significance	ns	ns	ns
Treatment	3 Weeks	5 Weeks	7 Weeks
Uncoated	10.86	16.25	18.56
Coated	8.21	10.99	12.55
Significance	***	***	***

Within columns of storage period (anova), temperature and treatment (t-test) means followed by a common letter do not differ significantly.
ns, *** nonsignificant or significant at P = 0.001.
± standard error of mean
non-parametric analysis
z 3, 5, 7 weeks = 2, 4, 6 weeks at 6°C plus 1 week at 20°C respectively.
y data at 6 and 9°C included

4.6.5 Colour

The mean L and H value decreased significantly during the first 3 weeks storage in all treatments (Table 13). The overall changes in the L and H values were small.

Table 13. Effect of coating, temperature and storage duration on the skin colour of 'Silverhill' mandarin from Kerikeri in 1994.

Treatment	Temp (°C)	0Week	3Weeks[z]	5Weeks	7Weeks
L value					
control	6	68.4a	66.2b	65.9bc	65.4e
coated	6	68.4a	65.7b	65.7bcd	64.6e
control	9	68.4a	66.3b	65.3cde	65.6e
coated	9	68.4a	66.1b	64.9de	65.2e
H value					
control	6	68.8a	64.1cde	64.5dc	64.0cde
coated	6	68.8a	65.03bc	64.4cd	62.9e
control	9	74.8a	63.6de	64.6dc	65.8b
coated	9	74.8a	64.1cde	63.0e	63.3de

Within columns (L or H) , means followed by a common letter do not differ significantly at P = 0.05, according to lsd test.
z 3, 5, 7 weeks = 2, 4, 6 weeks at 6°C plus 1 week at 20°C respectively.

4.7 Effect of temperature, storage period and polyethylene coating on quality of Gisborne 'Miyagawa' fruit harvested on 20 July 1994

4.7.1 TSS

Storage period had a significant effect on TSS in fruit of 'Miyagawa' stored on 20 July in 6°C cold storage for 6 weeks and 1 week at 20°C. The TSS in juice of fruit stored increased from 10.18% to 11.64% during 7 weeks storage (Table 14).

Temperature had no effect on juice TSS of stored fruit. Polyethylene coated fruit had significantly lower TSS than coated fruit only at 3 weeks storage (2 weeks at 6°C and 1 week at 20°C).

4.7.2 Titratable acidity

Acid loss occured in the first 3 weeks storage with no further loss up to 5 or 7 weeks. Coating had no effect on acidity in cv Miyagawa during the 7 weeks storage (table 14). The acidity in juice of stored fruit was lower in fruit stored at 9°C than fruit at 6°C. at 3 and 5 weeks storage.

4.7.3 TSS : acid ratio

The ratio increased significantly only after 3 weeks storage (8.87 to 11.69). Coating did not influence the TSS: acid ratio during storage. The TSS : Acid ratio was significantly higher in fruit stored at 9°C than at 6°C only at 3 weeks storage (Table 14). However uncoated fruit stored for 6 weeks at 6°C and 1 week at 20°C had significantly higher TSS:acid ratio.

Table 14. Effect of storage period, temperature and polyethylene coating on internal quality of late harvest Gisborne 'Miyagawa' (1994).

Storage Period[y]	TSS(%)	Acidity (%)	Ratio
0 weeks	10.18c	1.17a	8.87b
3 weeks[z]	11.09b	0.97b	11.69a
5 weeks	11.21b	1.00b	11.50a
7 weeks	11.64a	0.94b	13.03a
Significance	**	*	**
Temp(°C) 3 Weeks			
6	10.97 ± 0.13	1.03 ± 0.03	11.05a
9	11.20 ± 0.16	0.94 ± 0.03	12.33b
Significance	ns	ns	*
Treatment			
Uncoated	11.36 ± 0.13	0.99 ± 0.04	11.69 ± 0.51
Coated	10.81 ± 0.12	0.94 ± 0.03	11.68 ± 0.45
Significance	ns	ns	ns

Within columns of storage period (anova), temperature and treatment (t-test) means followed by a common letter do not differ significantly.
ns, *, **, *** nonsignificant or significant at P = 0.05, P = 0.01 and P = 0.001 respectively.
± standard error of mean.
ratio analyzed using non parametric analysis.
z 3, 5, 7 weeks = 2, 4, 6 weeks at 6°C plus 1 week at 20°C respectively.
y data at 6 and 9°C included

4.7.4 Weight loss

Fruit coated with polyethylene had a lower weight loss than uncoated fruit (Table 15). The weight loss in fruit increased as the storage period progressed ranging from 8.88% to 15.40%. The weight loss in fruit stored at 6°C and 9°C was similar.

Table 15. Effect of temperature, storage period and coating on percentage weight loss in cv Miyagawa from late harvest in Gisborne in 1994.

Storage Period^y	Percentage Weight Loss		
3 Weeks^z	8.88c		
5 Weeks	11.26b		
7 Weeks	15.40a		
Significance	**		
Temp(°C)	3 Weeks	5 Weeks	7 Weeks
6	9.07 ± .25	11.27 ± .48	15.40
9	8.66 ± .36	11.26 ± .39	-
Significance	ns	ns	
Treatment	3 Weeks	5 Weeks	7 Weeks
Uncoated	9.62	12.99	17.34
Coated	8.26	9.57	13.45
Significance	**	***	***

Within columns of storage period (anova), temperature and treatment (t-test) means followed by a common letter do not differ significantly.
ns, *** nonsignificant or significant at P = 0.001.
± standard error of mean
non parametric analysis.
z 3, 5, 7 weeks = 2, 4, 6 weeks at 6°C plus 1 week at 20°C respectively.
y data at 6 and 9°C included

4.7.5 Colour

The mean L and H value fell significantly during 3 weeks storage except in uncoated fruit stored at 9°C which had significantly lower L value after 5 weeks storage (Table 16). The over all change in the L and H values were small.

Table 16. Effect of polyethylene coating, temperature and storage duration on the skin colour of 'Miyagawa' mandarin from Gisborne in 1994.

Treatment	Temp (°C)	0Week	3Weeks[z]	5Weeks	7Weeks
L value					
control	6	68.0a	66.7bc	65.4d	66.0cd
wax	6	68.0a	66.1cd	65.4d	65.6d
control	9	68.0a	67.2ab	66.2cd	-
wax	9	67.9a	66.6bc	66.2cd	-
H value					
control	6	66.9a	65.1bc	64.3dc	65.0bc
wax	6	66.8a	64.5cd	63.6d	64.1cd
control	9	66.8a	65.5cd	64.9bc	-
wax	9	66.8a	64.5cd	64.5cd	-

Within columns (L or H) , means followed by a common letter do not differ significantly at P = 0.05, according to lsd test.
z 3, 5, 7 weeks = 2, 4, 6 weeks at 6°C plus 1 week at 20°C respectively.

4.8 Sensory evaluation

A sensory panel detected juice of 'Silverhill' to be lower in acidity, sweetness and had less mandarin flavour overall than juice of 'Miyagawa' (Table 17A). The panel was also able to identify a reduction in acidity only in 'Silverhill' as storage period progressed and more pronounced at 3 weeks storage period than at other storage periods. Sweetness increased in both cultivars as storage period increased whereas mandarin flavour increase only in 'Silverhill' (Table 17B). The sensory panel was notable to detect differences in acidity, sweetness and mandarin flavour between uncoated and coated fruit and between different picks. 'Citrus Gleam' coated fruit of 'Miyagawa' and 'Silverhill' harvested on 21 April and 28 July developed off-flavours which were detected by the panellist. However no off-flavours were detected in juice of polyethylene coated fruit from late harvest of both cultivars .

Table 17. The mean scoring of acidity, sweetness and mandarin flavour characteristics (A) overall means scoring for 4 storage periods (0, 3, 5 and 7 weeks) and 2 harvest of each cultivar ('Miyagawa' harvest 21 April and 20 July) and ('Silverhill' 28 April and 20 July) in 1994 in fruit stored at 6°C plus 1 week at 20°C. (B) of juice of each cultivar stored at each storage periods at 6°C plus 1 week at 20°C.

(A)	'Miyagawa'	'Silverhill'	Significance
Acidity	2.94	2.46	***
Sweetness	3.37	2.93	**
Mandarin Flavour	3.12	2.76	*

(B)	Day 0	Week3[z]	Week5	Week7	Significance
'Miyagawa'					
Acidity	3.21	2.79	2.92	2.82	ns
Sweetness	2.92a	3.35ab	3.54b	3.68b	*
Mandarin Flavour	3.21	2.92	3.21	3.14	ns
'Silverhill'					
Acidity	3.71a	1.89b	2.20b	2.04b	***
Sweetness	2.64a	2.82b	2.92b	3.36b	**
Mandarin Flavour	2.36a	2.44ab	2.91abc	3.32c	*

Acidity range 0 = very low, 6 = very acid
Sweetness range 0 = very low, 6 = very sweet
Mandarin flavour 0 = absent,6 = very strong.
z 3, 5, 7 weeks = 2, 4, 6 weeks at 6°C plus 1 week at 20°C respectively.
ns, *, **, *** nonsignificant or significant at P=0.05, P=0.01 respectively and means within a row followed by a common letter do not differ significantly according to ls means separation.

4.9 1995 Experiments

In the second season, number of experiments to further explore coatings with a range of products and also investigate their effects on internal gases were evaluated in 'Silverhill' fruit from Kerikeri. The results of this work are presented here.

4.9.1 Calibration of vials attached to mandarin fruit

The oxygen (O_2) concentration in vials attached to the skin of mandarin held at 6°C decreased rapidly after the vials were sealed and reached equilibrium level after 20 hours in uncoated and polyethylene coated fruit (Fig 6). In Carnauba coated fruit, vial O_2 concentration reached equilibrium level after 70 hours, 'Citrus Gleam' coated fruit required at least 133 hours from sealing.

The CO_2 concentration in vials increased rapidly within 10 hours from sealing in all treatments and reached an equilibrium in coated fruit after 77 hours while in uncoated fruit CO_2 concentration was steadily increasing 133 hours after sealing (Fig 7).

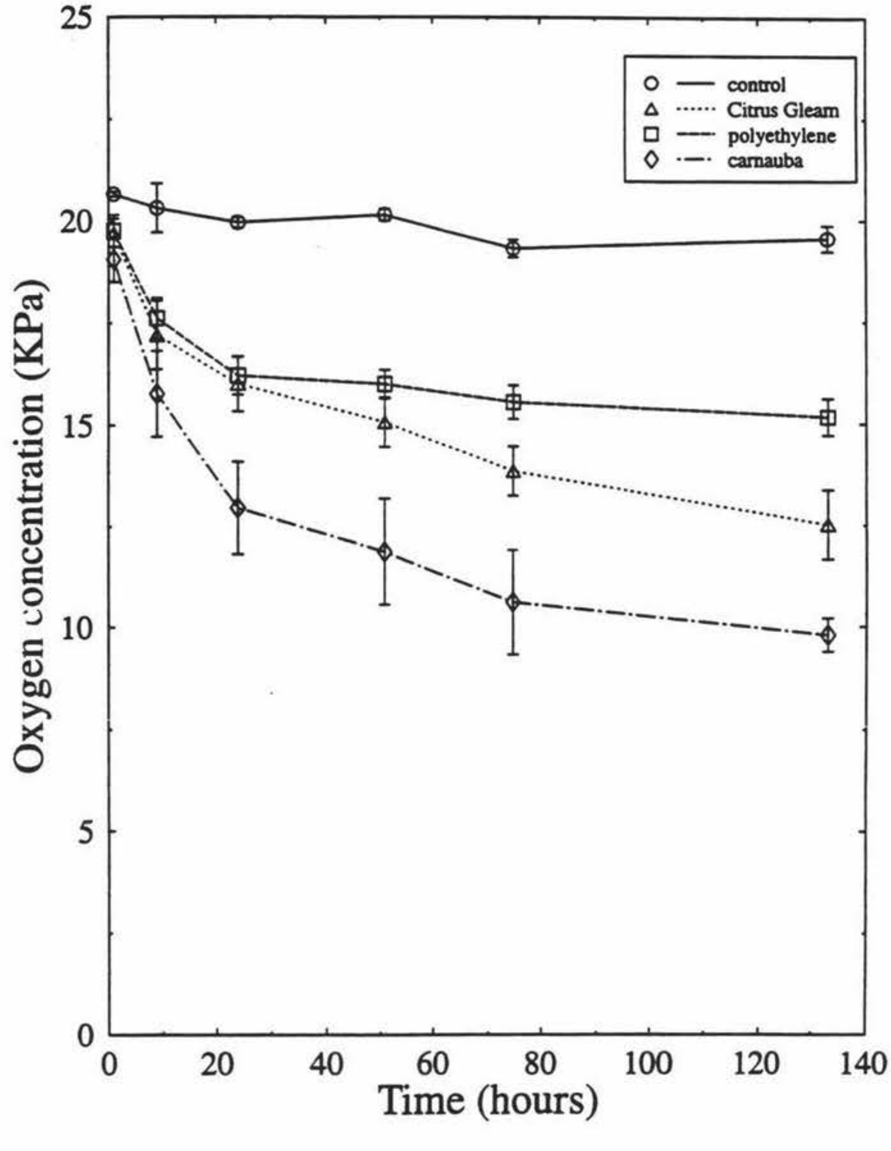


Figure 6. Changes in vial oxygen concentration during storage 6^0C of 'Silverhill' mandarin fruit. Vertical bars represent standard error of the mean.

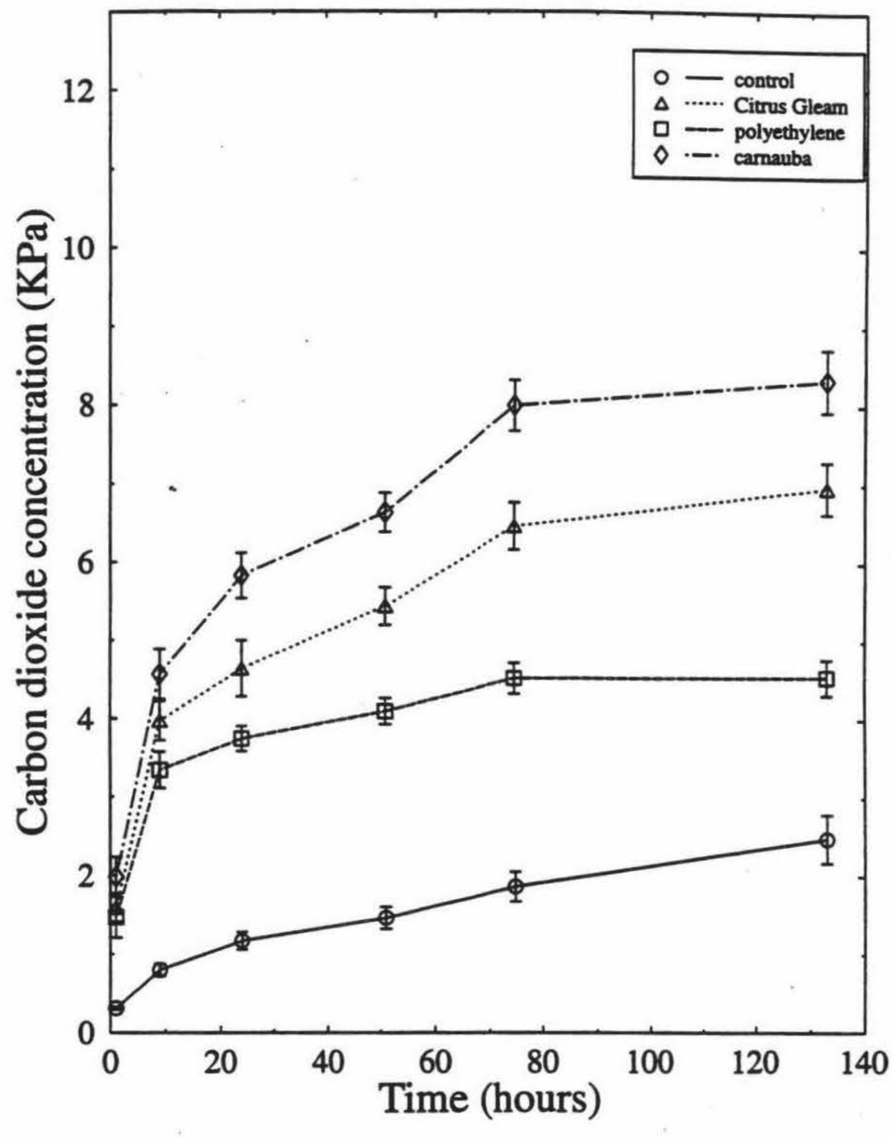


Figure 7 Changes in vial carbon dioxide concentration during storage 6^{0}C in 'Silverhill' mandarin fruit. Vertical bars represent the standard error of mean.

4.9.2 Changes in the sub-epidermal internal atmosphere during cool storage of coated 'Silverhill' satsuma mandarin in 1995

Within 2 days coated fruits had significantly lower internal oxygen level compared with uncoated fruit stored at 6°C (Table 18). Fruits coated with carnauba had the lowest O_2 concentration throughout the storage period. There was no significant difference in O_2 concentration in 'Citrus Gleam' and polyethylene coated fruit during storage.

The concentration of oxygen decreased rapidly in fruit stored for one week at 20°C after 6 weeks at 6°C in all treatments with a decrease in all fruit of about 5.6KPa in one week (Table 18). Fruit coated with carnauba had only 20% the O_2 concentration of other treatments at the end of the experiment.

The CO_2 concentration increased in all treatments during storage (Table 18). uncoated fruit had lower internal CO_2 than coated fruit throughout the storage period. Carnauba coated fruit accumulated the highest concentration of internal CO_2 during cold storage of all coatings tested. The CO_2 concentration in fruit coated with 'Citrus Gleam' and polyethylene did not differ significantly during storage. After 7 weeks storage, the CO_2 concentration in carnauba coated fruit was almost double that of fruit treated with 'Citrus Gleam'.

4.9.3 Weight Loss in coated 'Silverhill' fruit during cool storage in 1995

Uncoated fruit stored for 21 days or more lost more weight than coated fruit (Table 19). All coatings reduced weight loss to approximately the same degree during storage at 6°C with relative humidity of 75%. In general weight loss in fruit increased steadily during 6 weeks storage at 6°C but it doubled when stored for one week at 20°C.

4.9.4 Internal composition changes in coated 'Silverhill' satsuma fruit during cool storage (1995)

The juice TSS in all fruit coated remained similar during storage for 49 days (Table 20). The titratable acidity decreased significantly in all treatments during storage (Table 20). 'Citrus Gleam' and polyethylene coated fruit had significantly lower acidity compared with uncoated fruit after 49 days of storage.

The TSS:acid ratio increased significantly during 49 days storage in all the treatments (Table 20), but there was no significant difference between treatments.

Table 18. Effect of coatings on sub-epidermal gases (O_2 and CO_2) in 'Silverhill' mandarin during 42 days storage at 6°C followed by 7 days at 20°C in 1995.

Treatment	Oxygen (KPa)					Carbon dioxide (KPa)				
	Day2 (6°C)	Day14	Day21	Day42	Day49 (20°C)	Day2 (6°C)	Day14	Day21	Day42	Day49 (20°C)
Control	19.9a	17.8a	16.2a	16.5a	9.9a	1.2d	2.3b	2.8c	2.7c	4.1c
'Citrus Gleam'	16.3b	14.2b	11.2b	14.0a	9.5a	4.5b	3.5a	4.6b	4.2b	6.1b
Polyethylene	15.9b	15.0ab	13.9ab	15.0a	9.2a	3.7c	3.3a	4.0b	3.5b	5.5b
Carnauba	12.0c	12.0b	8.2c	7.3b	1.8b	5.7a	3.3a	5.6a	6.0a	12.0a

Within columns, means followed by a common letter do not differ significantly at P = 0.05, according to lsd test.
Repeated measures analysis.

Table 19. Effect of waxes on percentage weight loss in satsuma mandarin during storage at 6°C (42 days) followed by 1 week at 20°C (1995).

Treatment	Percentage Weight Loss			
	Day14	Day21	Day42	Day49
Control	2.1a	3.9a	5.1a	13.7a
Citrus Gleam	2.0ab	3.3b	4.1b	10.3b
Polyethylene	1.9b	3.1b	4.2b	9.4c
Carnauba	2.2a	3.4b	4.5b	9.7bc

Within columns, means followed by a common letter do not differ significantly at P = 0.05, according to lsd test.
non parametric analysis.

Table 20. Effect of coatings on internal quality of 'Silverhill' satsuma mandarin during storage in 1995.

Treatment	TSS	Acid	TSS:Acid ratio
0 DAYS Storage			
Control	8.3ab	0.89a	9.5b
49 DAYS Storage			
Control	8.8a	0.77b	11.6a
Citrus Gleam	7.9b	0.65c	12.1a
Polyethylene	8.1b	0.66c	12.3a
Carnauba	8.1b	0.70bc	11.5a

Within columns, means followed by a common letter do not differ significantly at P = 0.05, according to lsd test.

4.9.5 Effect of picking date and coating on volatile production in 'Silverhill' mandarin during storage

The coatings carnauba, polyethylene and 'Citrus Gleam' and storage period had similar levels of acetaldehyde except for May pick at 20°C for one week had higher levels of acetaldehyde.

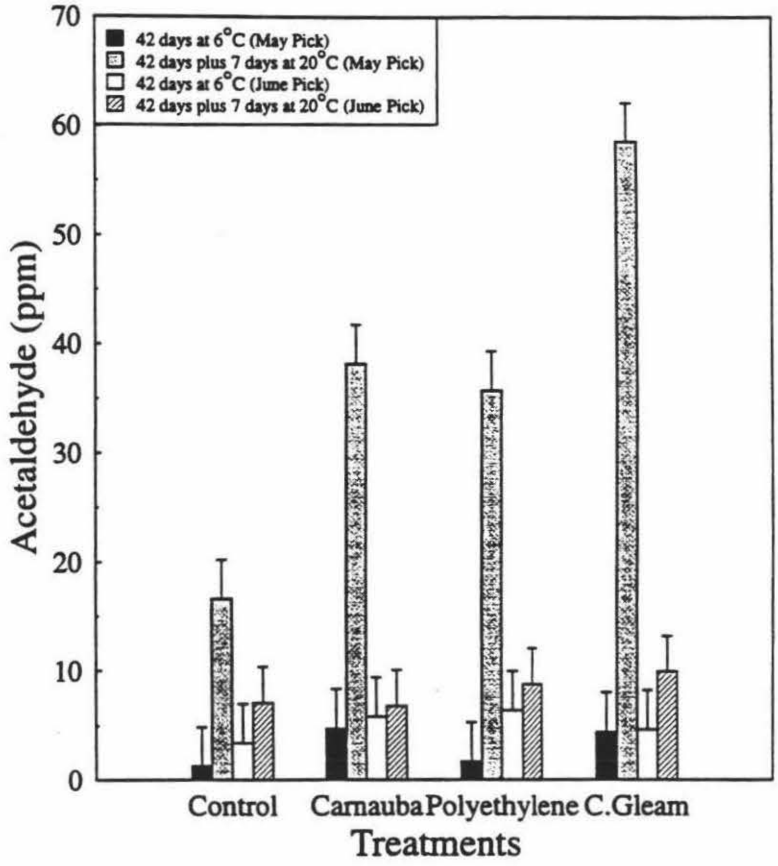


Figure 8. The effect of pick date and treatment on the level of acetaldehyde during storage and shelf-life of 'Silverhill' mandarin fruit. Vertical bars indicate standard error of the mean.

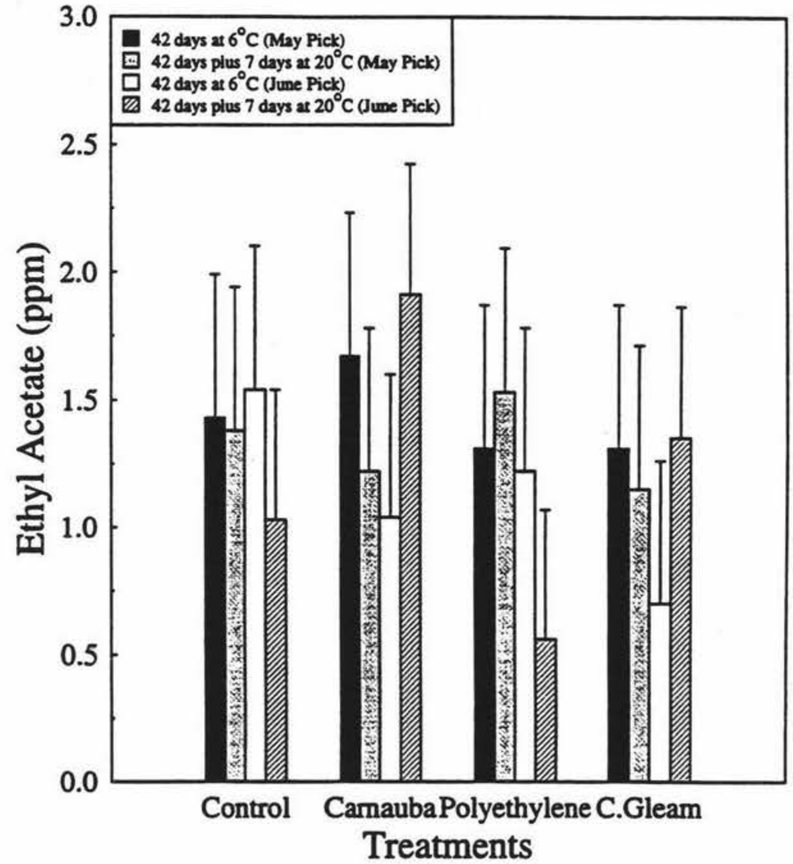


Figure 9. The effect of pick date and treatment on the level of ethyl acetate during storage and shelf-life of 'Silverhill' mandarin. Vertical bars indicate standard error of the mean.

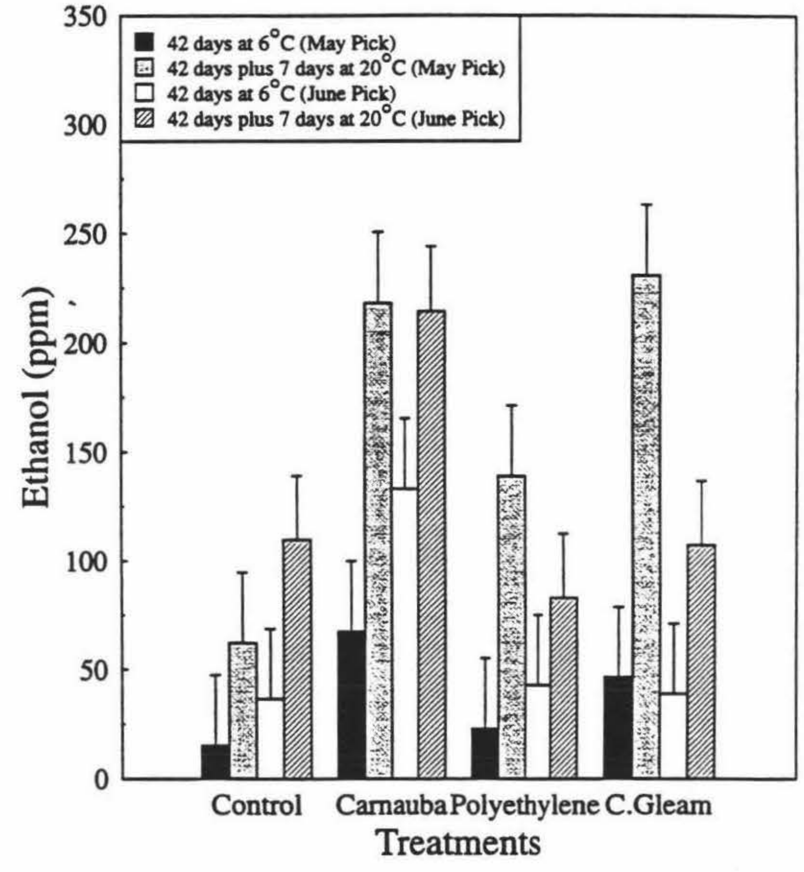


Figure 10 The effect of pick date and treatment on the level of head space ethanol during storage and shelf-life of 'Silverhill' mandarin fruit. Vertical bars indicate standard error of the mean.

During this period the coated fruit had a higher level of acetaldehyde than uncoated fruit. 'Citrus Gleam' coated fruit had the highest (58.5ppm) concentration of acetaldehyde with carnauba and polyethylene having similar results of fruit in May pick stored at 20°C. All stored fruit had a similar ethyl acetate level during each storage period. The level of the ethyl acetate was not affected by picking date (Fig 9).

Picking date and storage period affected the concentration of ethanol in stored fruit. During cold storage and the subsequent shelf-life period carnauba coated fruit usually accumulated the highest level of ethanol (Fig 10). Polyethylene coated fruit had similar level of ethanol as uncoated fruit.

4.10 Effects of application methods of coatings on stored mandarin

4.10.1 Internal gas composition

After 3 days storage at 6°C 'Citrus Gleam' coated fruit (2 dips) had the lowest vial O_2 level (12KPa) and continued to have lower O_2 throughout storage decreasing by approximately fifty percent at each measurement (Table 21). Fruit coated with polyethylene (2 dips) had similar O_2 concentration as polyethylene (brush) as storage progressed but had significantly lower O_2 concentration (4.3 and 3.2 KPa after 21 and 28 days respectively compared to the 1 dip treatment.

The O_2 concentrations were not significantly different during storage between fruit coated by brushing with polyethylene and 'Citrus Gleam'.

Table 21. Effect of method of wax application on sub-epidermal internal atmosphere of 'Silverhill' fruit after 6°C cool storage and 1 week at 20°C in 1995.

Treatment	Oxygen (KPa)			Carbon dioxide (KPa)		
	Day 3 (6°C)	Day 21	Day 42	Day3 (6°C)	Day 21	Day 42
Control	20.0a	19.1a	14.0a	1.0c	1.9d	3.3d
Polyethylene + 1 dip	17.9bc	17.3ab	11.2ab	2.7b	2.9c	4.7cd
Polyethylene + 2 dip	16.3c	13.0c	7.5c	3.1b	4.2ab	5.2cd
Polyethylene + brush	17.9bc	15.3bc	8.7bc	2.9b	3.8b	4.7cd
C. Gleam + 1 dip	18.5ab	13.1c	8.6c	3.1b	4.3ab	7.6b
C. Gleam + 2 dip	10.0d	5.5d	2.2d	4.9a	4.8a	16.6a
C. Gleam + brush	18.2ab	15.7b	9.8bc	2.9b	3.8b	6.5bc

Within columns, means followed by a common letter do not differ significantly at $p=0.05$, according to lsd test.
Fruit were stored for 21 and 35 days at 6°C and the latter fruit then held for 7 days at 20°C.
Repeated measures analysis.

Polyethylene coated (1 dip) fruit had more O_2 (equivalent to partial pressures of 4.2KPa and 3.2KPa) than 'Citrus Gleam' coated (1 dip) fruit at 21 and 28 days storage respectively.

The O_2 concentration was not significantly different between 'Citrus Gleam' with 1 dip and 2 dips at 3 and 28 days storage but O_2 in 'Citrus Gleam' (2 dips) fruit were 8.5, 7.6 and 5.8KPa lower than 'Citrus Gleam' (1 dip) at 3, 21 and 28 days storage respectively.

'Citrus Gleam' (2 dips) coated fruit had the highest CO_2 concentration throughout the storage period compared to other treatments (Table 21). During the first 3 days storage uncoated fruit had the lowest CO_2 (1.0KPa) while 'Citrus Gleam' (2 dips) the highest (4.9KPa). There was no significant difference among other treatments in CO_2 concentration at 3 days storage at 6°C.

At 21 days cold storage uncoated fruit still had the lowest O_2 (1.0KPa) followed by polyethylene (1 dip - 2.9KPa) and 'Citrus Gleam' (2 dips) having the highest (4.8PKa) CO_2 concentration. Other treatments had similar CO_2 concentration. When fruit were stored for one week at 20°C Citrus Gleam (2 dips) coated fruit had the highest (16.6KPa) CO_2 concentration followed by 'Citrus Gleam' (1 dip) fruit (7.6KPa) and Citrus Gleam coated fruit by brush (6.5KPa). All polyethylene coated fruit had a similar CO_2 concentration to uncoated fruit (3.3KPa). 'Citrus Gleam' (brush) coated fruit did not differ significantly in CO_2 concentration from polyethylene coated fruit.

4.10.2 Effect of application methods on volatile production in 'Silverhill' mandarin during storage

The dip application produced significantly higher levels of ethanol and acetaldehyde than uncoated fruit. The fruit sprayed with 'Citrus Gleam' had a similar level of acetaldehyde and ethanol to the uncoated fruit after 14 days cold

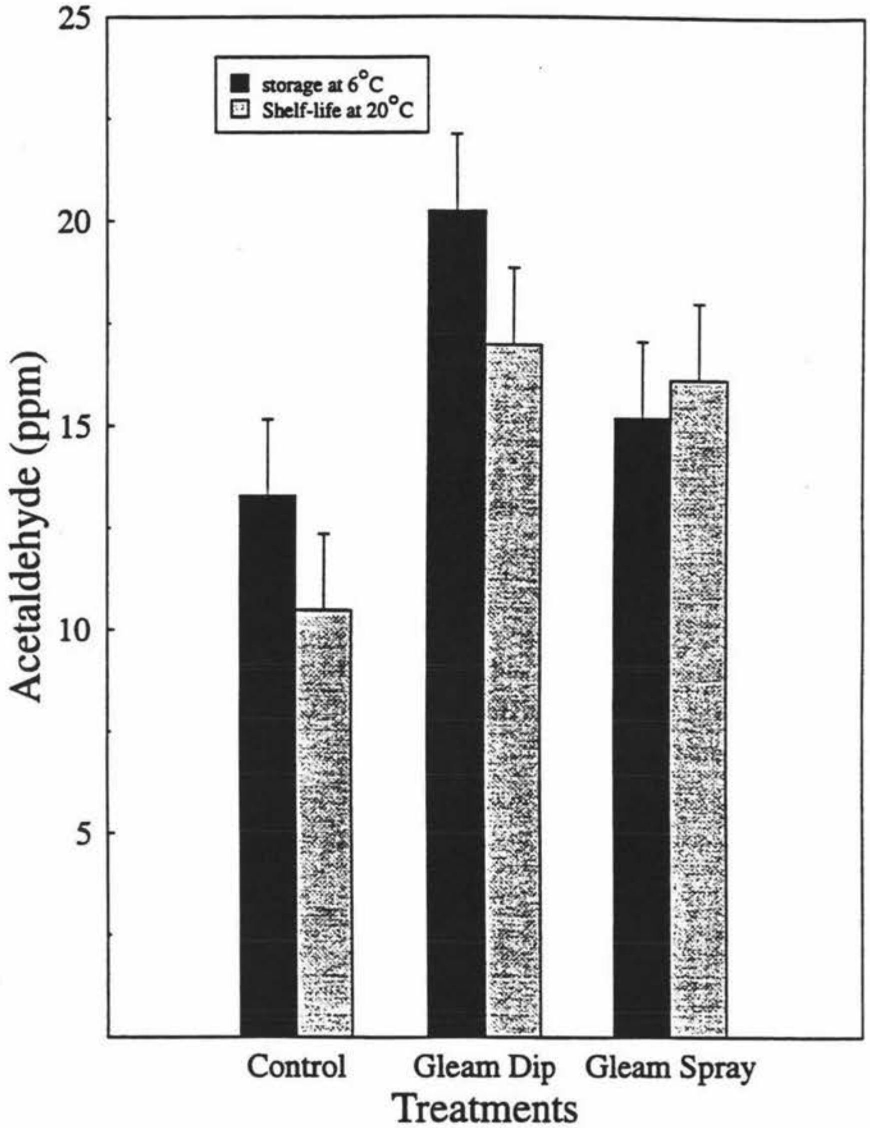


Figure 11. The effect of two methods of wax application on the level of juice acetaldehyde after 14 days storage at 6°C and 7 days shelf-life (20°C). Vertical bars indicate the standard error of the mean.

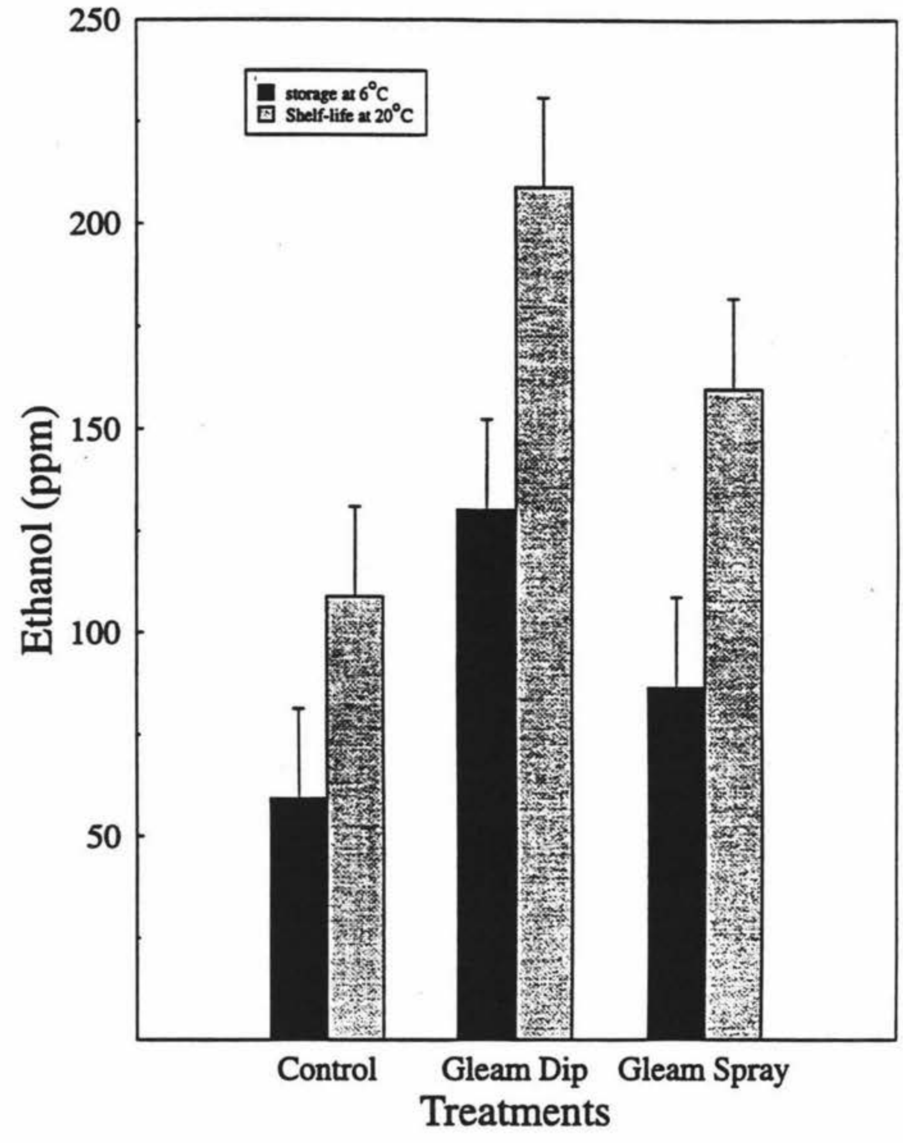


Figure 12 The effect of two methods of wax application on the level of juice ethanol after 14 days storage at 6°C and 7 days shelf-life (20°C). Vertical bars indicate the standard error of the mean.

but both were were lower than in dipped fruit. After 1 week at warm temperature of 20°C the volatile were significantly higher in all coated fruit than in control fruit (Fig 11 and 12).

4.10.3 Changes in internal quality of 'Silverhill' satsuma mandarin with different methods of coating application (1995)

The changes in TSS levels during this short 28 day storage were not significant but a significant decrease in acidity (1.11% to 0.85 - 0.94) gave rise to a marked improvement in the TSS:Acid ratio ranging from 9.2 to 10.2 (Table 22).

Table 22. Effect of application methods of surface coating on the internal quality of 'Silverhill' satsuma mandarin (Harvest 22 May, 1995).

Treatment	TSS	Acid	Ratio
0 Days			
Control (uncoated)	8.6	1.11a	7.8c
28 Days			
Control	8.6	0.85c	10.2a
Polyethylene + 1 dip	8.6	0.94b	9.2b
Polyethylene + 2 dip	8.6	0.86bc	10.2a
Polyethylene + brush	8.9	0.92bc	9.8ab
'Citrus Gleam' + 1 dip	8.8	0.88bc	10.0ab
'Citrus Gleam' + 2 dip	9.0	0.92bc	9.8ab
'Citrus Gleam' + brush	8.7	0.93bc	9.4ab

Within columns, means followed by a common letter do not differ significantly at P = 0.05, according to lsd test.

4.10.4 Effect of methods of application of coatings on weight loss in 'Silverhill' fruit (1995)

For both 'Citrus Gleam' and polyethylene coatings, all methods of application reduced weight loss by approximately 26% over uncoated fruit during 21 days cool storage at 6°C (Table 23), although this difference did not reach statistical significance ($p > .05$). When these fruit were stored for one week at 20°C, weight loss increased markedly and uncoated fruit had the highest weight loss of 12.1% followed by 'Citrus Gleam' (brush), polyethylene (brush) and 'Citrus Gleam' (1 dip) of 9.0, 8.5 and 8.4% respectively. When Polyethylene was applied by brush weight loss was greater than following either dip treatment.

Table 23. Effect of methods of coating application on weight loss in cv Silverhill satsuma mandarin in 1995.

Treatment	Percentage Weight Loss	
	Day 21 (6°C)	Day 28 (20°C)
uncoated control	2.7	12.1a
Polyethylene + 1 dip	1.9	7.3d
Polyethylene + 2 dip	2.0	7.1d
Polyethylene + brush	2.2	8.5bc
'Citrus Gleam' + 1 dip	2.0	8.4bc
'Citrus Gleam' + 2 dip	1.9	7.9cd
'Citrus Gleam' + brush	2.1	9.0b

Within columns, means followed by a common letter do not differ significantly at p=0.05, according to lsd test.
Non parametric analysis

4.10.5 Effects of spray vs dipping of 'Citrus Gleam' on internal gases of 'Silverhill' fruit during storage (1995)

There was a significant difference in core CO_2 and O_2 concentration between treatments after each storage period (Table 24). The CO_2 concentration of fruit dipped in 'Citrus Gleam' was 5.2 and 6.9KPa greater than uncoated fruit after 14 and 21 days storage respectively. When fruit were sprayed with this coating the elevation in CO_2 levels was less pronounced. During 14 days storage O_2 concentration decreased 75% and 29% in dipped and sprayed treatments respectively compared with uncoated fruit. Internal oxygen level declined further by approximately 45% in both sprayed and dipped fruit after 21 days storage.

Table 24. Effects of spray and dip application of 'Citrus Gleam' (C.Gleam) on internal (KPa) gases in the core of 'Silverhill' mandarin during storage (1995).

Treatment	CO_2 (KPa)	O_2 (KPa)
Day 14^z		
Control	3.7c	14.3a
C.Gleam - dip	8.9ab	3.6d
C.Gleam - Spray	4.8c	10.2b
Day 21		
Control	3.5c	14.2a
C.Gleam - dip	10.4a	2.0d
C.Gleam - Spray	7.6b	5.7c

Within columns, means followed by a common letter do not differ significantly at P = 0.05, according to lsd test.
z day 14 and 21 = 7 and 14 days storage at 6°C and 7 days at20°C.

4.10.6 Effect of 'Citrus Gleam' application methods on internal quality of cv Silverhill mandarin during storage

The TSS remained similar during storage in all treatments (Table 25). Titratable acidity remained largely unchanged but there was a small increase in the TSS:acid ratio for all treatments. Acidity tended to drop more in dipped fruit than sprayed or uncoated fruit.

Table 25. Effect of 'Citrus Gleam' application methods on internal quality of 'Silverhill' mandarin in 1995.

Treatment	TSS(%)	Acidity(%)	TSS : Acid Ratio
0 Days			
Control	8.4abc	1.06a	7.93d
Spray	8.4abc	1.06a	7.93d
Dip	8.4abc	1.06a	7.93d
14 Days			
Control	8.7a	0.99ab	8.91bc
Spray	7.9c	0.84dc	9.61abc
Dip	8.1bc	0.80d	10.12a
21 Days			
Control	8.7a	0.99ab	8.63c
Spray	8.5ab	0.96ab	8.75c
Dip	8.6ab	0.91bc	9.51abc

Within columns, means followed by a common letter do not differ significantly at p=0.05, according to lsd test.

CHAPTER 5 DISCUSSION

5.1 The seasonal pattern of mandarin fruit maturation

The TSS:acid ratio of 10:1 and TSS of 10%, the minimum export standard to Japan were not achieved in either mandarin cultivar during the 1994 harvest season in samples collected in the 3 main growing areas of New Zealand. Fruit from Bay of Plenty (BOP) had the maximum TSS lower than 9% and high titratable acidity (1.2 - 2.2%) thus the TSS:acid remained lower than 6:1 in 'Miyagawa' and 8:1 in 'Silverhill'. The minimum maturity index for local market fresh fruit of 7:1 was not achieved in juice of 'Miyagawa' harvested in Tauranga in 1994 whereas in 'Silverhill' this value was reached in the late harvest (13 July). At late harvest some fruit of both cultivars had flesh dryness and puffy skin. Dawes and Martin (1991) also found low TSS:acid ratio (<8.0) in mandarin cultivars over 7 years period at Bay of Plenty. Based on these limited data it appears likely exportable mandarin fruit can not be grown in Bay of Plenty without a significant change in climatic conditions, management practices, postharvest management or cultivars. For the local market 'Silverhill' harvested late in the season (after mid July) would be the preferred cultivar than 'Miyagawa'. TSS in the juice of cv Miyagawa at Kerikeri and Gisborne just reached 10% (the minimum for export) during the harvest season of 21 April to 9 June (Fig 3A and Fig 3A). However the titratable acidity remained above one percent during the harvest period which lowered the TSS:acid ratio to a level unacceptable in the Japanese market. At the point of sale in Japan the satsuma juice acidity should be 0.8% (Harty and Anderson, 1995). Thus it is the high level of titratable acidity in Satsuma grown in New Zealand that reduces the quantity of exportable grade mandarin. The TSS:acid ratio in juice of 'Miyagawa' reached the minimum commercial maturity of 7:1 on 6 May at Kerikeri and remained similar until 9 June. In 'Silverhill' the ratio reached 8:1 on 11 May and fluctuated around that ratio during the harvest period (11 May to 20 July). Since juice of 'Silverhill' fruit reached higher internal quality than 'Miyagawa', the former cultivar would be the preferred cultivar at Kerikeri although it matured 1 week earlier. Both cultivars did not reach the export quality requirement to Japan. Fruit of 'Miyagawa' from

Gisborne reached minimum commercial maturity of 7:1 about 3 weeks earlier (20 May) than 'Silverhill' fruit. As harvesting progressed the TSS:acid ratio reached 9.5:1 in 'Silverhill' and 9:1 in 'Miyagawa' on 20 July. Both cultivars in Gisborne attained better internal quality for the local market although 'Miyagawa' was 3 weeks earlier in harvest. As at Kerikeri and Bay of Plenty the juice TSS:acid ratio in both cultivars did not reach the export requirement (10:1). In the present study 'Miyagawa' reached minimum commercial maturity (7:1) on 6 May, 20 May at Kerikeri and Gisborne respectively. 'Silverhill', a mid-season cultivar (mid May to early June) reached the minimum acceptable maturity in early May and early June at Kerikeri and Gisborne respectively. The results confirm that citrus fruit reach commercial maturity earlier at Kerikeri followed by Gisborne and BOP (Fletcher and Hollies. 1965).

Climate especially temperature has a significant effect on fruit growth and quality as clearly demonstrated by Reuther and Rios-Castano (1969) when they compared various fruit quality factors in tropical areas of Colombia with arid and coastal subtropical regions of California. They found that fruit growth rate within each climatic region was primarily a function of temperature. It is the total heat available during the growing season that has a marked influence on the growth rate and time of ripening of citrus fruit. In Australia and California with a heat index of 2700 to 3400 day degrees above 14°C, oranges mature earlier and normally have a higher TSS to acid ratio than oranges grown in New Zealand where temperatures are cooler (1300 to 2100 day degrees) (Fletcher and Hollies, 1965). Long term temperature records (Appendix 1) show that optimal conditions for citrus growth are rare in the main citrus growing areas of New Zealand (Richardson et al., 1991). During maturation mean temperatures greater than 20°C are required to decrease acidity levels within the fruit (Kurihara, 1969, 1971; Ni et al., 1970). The mean monthly temperatures in NZ growing districts are below 20°C during fruit maturation (February to May) (Appendix I), thus the acidity remains high and as result the TSS:acid ratio in fruit juice remains low . Citrus TSS appear to be elevated by warm night temperatures throughout fruit growth and moderate night temperatures (15-20°C) after fruit begin to colour (Nii et al., 1970).

The heat units available in the northern New Zealand citrus growing districts such as Kerikeri (1795-2107) are much greater than at Bay of Plenty (1347-1696) (Fletcher and Hollies,1965). A difference such as this provides a major explanation for the higher internal quality of Satsuma mandarin grown at Kerikeri compared with fruit from Bay of Plenty.

Although the internal fruit quality varies from district to district considerable improvement needs to be made to the internal fruit quality of satsuma before a high proportion of the fruit will meet minimum export standard. In Japan large areas of satsuma mandarin are grown under cover with controlled temperature for the high quality off season market with its premium prices. In recent studies in New Zealand manipulation of microclimate within citrus orchards by tunnel house (Martin, 1991) and plastic mulches (Richardson et al., 1993) show promise in improving the internal fruit quality. Further studies and recommendations in use of plastic mulches on improvement in internal quality of fruit would provide growers a further choice to improve the quality of satsuma fruit for export. Tunnel houses seem to be too expensive for growers to use. Management practices such as thinning, soil moisture control by mounding or water stress at a specific time of fruit growth would help in improving the quality of satsuma fruit.

Fruit of cvs Miyagawa and Silverhill from all three districts had achieved good orange coloured peel (Tables 4,5 and 6). The H and L values which measures the hue and lightness of the colour were similar in fruit from all districts and harvest dates except in the first pick fruit were greener. This confirms satsuma fruit grown in New Zealand (NZ) achieve a good orange coloured peel due to cool autumn temperatures as they mature. Cool temperatures 2-4 months before harvest stimulate the breakdown of chlorophyll in the fruit rind and enhances fruit colouring.

5.2 Influence of storage conditions on mandarin quality

Although the respiratory rates of mature citrus fruits are relatively low, extended post harvest storage results in internal quality changes (Purvis, 1983). In the present trials, cool storage of two satsuma cultivars led to improved fruit quality through decreasing juice titratable acidity with a consequent increase in TSS:acid ratio (Tables 7a, 7b,11 and 14). The marked increases in this ratio obtained in storage has considerable potential to benefit the New Zealand mandarin industry. For example in this study fruit that did not reach export standards at harvest, did meet them after about 1 month in store (TSS:acid ratio increased from 8.87 to 11.69 at 3 weeks storage of 'Miyagawa'). In late harvested 'Miyagawa' from Gisborne the TSS increased steadily during storage (Table 14) an effect not found in all other comparisons. Similar increases in TSS have been previously reported for 'Pineapple' and 'Valencia' oranges stored for 6 weeks at 4°C and 12 weeks at 1°C, respectively (Davis et al., 1973). However El-Zeftavi (1976) found an increase in TSS for 6 weeks followed by an eventual decline in 'Valencia' oranges stored at 5°C for 24 weeks. Beever (1990) did not find significant increases in TSS during 10 weeks storage of New Zealand 'Miyagawa' mandarin at 5°C. Echeverria and Ismail (1984) concluded that TSS in sweet oranges and tangerines increased for a time during storage which could be attributed to a concurrent increase in sucrose content.

The titratable acidity of the juice of stored fruit of cvs Silverhill and Miyagawa decreased as the storage duration increased as reported for sweet citrus by several workers (Beever, 1990; Echeverria and Ismail, 1987; Davies et al., 1973; Ahmad, 1987; Sasson and Monselise, 1977; Purvis., 1983; Cohen et al., 1991). The decrease in acid concentration is a consequence of respiratory activity (Purvis, 1983). Although peel tissue has higher respiratory activity than the juice sacs, respiratory activity of the juice sacs results in internal quality changes of the fruit during storage. The acid requirement in satsuma mandarin at the point of sale in Japan is that it should be 0.8% (Harty and Anderson 1995). During storage for up to 6 weeks at 6°C or 9°C plus one week at 20°C the juice acidity of fruit gradually fell but remained above 0.8% in all experiments except in 'Silverhill' fruit harvested late in the season (20 July) at Kerikeri where acidity decreased to 0.7% after 6 weeks storage at 9°C followed by 1 week at 20°C. The rate of acidity reduction during storage depended on cultivar and time of harvest. In early harvested 'Silverhill' (11 May) the acidity reduced 13% in the first 3 weeks (from 1.2 to 1.04%) followed by a 5% reduction for each subsequent two weeks in storage. This compared with 17% (from 1.24%) reduction in 3 weeks, 17% in 5 weeks and 6% in 7 weeks in late harvested 'Silverhill' (20 July). In early harvested 'Miyagawa' (21 April) there was 17% reduction in acidity in the first 3 weeks (from 1.17 to 0.97%) followed by a further 11% drop over the next 2 weeks. The acidity decreased only 1.8% in the first 3 weeks and remained unchanged over the next 5 weeks storage in late harvested Gisborne 'Miyagawa'(20 July). In 1995 acid concentration in coated 'Silverhill' fruits stored on 24 May decreased 19% after 21 days cool storage (6°C) and 7 days at 20°C. 'Silverhill' fruit stored on 13 June had a 21% decrease in acidity at 42 days cool storage (6°C) and 7 days at 20°C. From the results, the greatest loss in acidity occurred in the first 3 weeks of storage, but continued throughout cold storage.

Fruit of both cultivars stored at 9°C tended to have lower titratable acidity than fruit stored at 6°C in cvs Silverhill and Miyagawa with no effect on TSS (Tables 11 and 14). The greater reduction in acid concentration at the higher temperature suggests it increases organic acid utilisation as a respiratory substrate (Purivs, 1983). Temperature is one of the most important environmental factors that influence the deterioration rate of stored commodities. Low temperatures depress fruit respiration, water loss and growth of decay organisms. The rate of respiration is generally considered to be doubled by a rise of temperature of 10°C. Mandarins can normally tolerate slightly lower temperatures than many other citrus but storage at 0°C leads to chilling injury (Beever, 1990). Wills et al.,(1989) recommended mandarins be stored for 4 - 6 weeks at 5 to 9°C. In the present study mandarin fruit stored from 2 to 6 weeks at temperatures of 6°C and 9°C plus 1 week of shelf life at 20°C improved in internal quality suitable for export. The increase in TSS:acid ratio during storage depended on the amount of acid in fruit at time of storage and the rate of reduction of acid in stored fruit. Fruit of early harvest had higher juice acid levels than late harvested fruit. For example Kerikeri 'Miyagawa' picked at ratio 7.12 in May 5 weeks storage to reach 9.80:1, whereas fruit picked 10 weeks later at 8.87 (Gisborne) required only 3 weeks to reach 11.69:1. The present results confirm Beever's (1990) findings of significant quality improvement in cv Miyagawa stored at 5°C for 6 weeks with a further two weeks at 20°C. Similarly Cohen et al., (1991) found the optimal storage temperature for 'Nova' mandarin was 5°C.

Generally waxing / coating has small but variable effects on the level of total soluble solids, titratable acidity and TSS:acid ratio in citrus fruit (Ahmad and Khan, 1987; Baldwin et al., 1995). In the present study, coated fruit in storage of both cultivars harvested in 1994 generally had a similar TSS and higher acidity than uncoated fruit thus a lower TSS:acid ratio. During 1995, 'Silverhill' fruit coated with different coatings had lower TSS and lower acidity than uncoated fruit. The decrease in TSS and acidity did not affect the TSS:acid ratio thus it did not affect the overall internal quality of the fruit. Fruit coated with 'Citrus Gleam' developed milky spots during storage when moisture was absorbed by the fruit. Kerifresh pckhouse had similar problems with 'Citrus Gleam' coated to wet fruit but not if coated to dry fruit.

Both mandarin cultivars in the present study stored at 60 to 65% relative humidity in the first 3 weeks lost more than 4% fresh weight and visibly showed signs of shrivelling. The percentage weight loss throughout the storage period rising to about 17% after 7 weeks was too high to be commercially acceptable. The rate of water loss is influenced by the relative pressure exerted by water vapour within and outside of the fruit (vapour pressure differential) (Grierson and Wardowski, 1975). Probably fruit stored in present study at low relative humidity (high vapour pressure deficit) had high weight loss. Oogaki and Manago (1977) found the most optimum humidity for log term storage of satsuma was 85-90% at which condition the loss of fruit weight per month was about 3%. Thus it is suggested that any further storage research on mandarin be carried out at high relative humidity. Purvis (1983) found fruit of 'Hamlin' oranges and 'Marsh' grapefruit lost moisture faster at 21°C than at 5°C. However in our study, there was no difference in weight loss of either coated or uncoated fruit at temperatures of 6°C and 9°C in both mandarin cultivars probably due to small differences in temperature range. However in coated and uncoated fruit weight loss doubled (9.5%) when fruit were stored at 20°C for 1 week compared with the same fruit stored at 6°C for 42 days (Table 19). Polyethylene coated fruit had lower weight loss though not significantly compared to other coatings. Fruit of late harvest uncoated 'Silverhill' lost approximately 6, 17 and 3% more weight at 3, 5, and 7 weeks storage than 'Miyagawa' a cultivar difference which may be due to smaller 'Silverhill' fruit and difference in natural wax coating.

The Hue angle value measured in fruit of the first pick in both cultivars in the 3 districts was significantly higher than in all later harvests showing that fruit skin at the first pick was greener. After the first harvest fruit had already developed bright orange colour, and during storage no colour change occurred compared to the time of harvest.

5.3 Use of surface coatings to maintain mandarin quality in storage

The application of surface coatings offers both advantages (eg. reduced weight loss) and disadvantage (eg. off-flavours) when used on fresh fruit. In this study to determine the characteristics of its use in the export mandarin industry it was found that while all coatings were equally effective in reducing weight loss up to 45%, a shellac based and a carnauba product rapidly developed undesirable internal changes in the fruit. It is clear the industry must carefully weigh up the diverse benefits and risks associated with the use of skin coatings in long term storage of mandarin fruit.

'Silverhill' mandarin that received any one of carnauba, 'Citrus Gleam' or polyethylene coating (dip) treatments exhibited a lower concentration of internal O_2 and a higher concentration of internal CO_2 (Table 18), compared with uncoated fruit during low temperature storage. Similar results have been reported by Ben-Yehoshua, 1969; Davis and Hofmann, 1973; Ben-Yehoshua et al., 1985; Nisperos-Carriedo et al., 1990; Hagenmaier and Baker, 1993 and Davis et al., 1967) with citrus fruit. In the present trial significant differences between coated and uncoated fruit in sub-epidermal concentration of oxygen and carbon dioxide were measured within 2 days of storage at 6°C. Carnauba, 'Citrus Gleam' and polyethylene coated fruit had 40%, 17%, 20% less O_2 and 79%, 51% and 67% more CO_2 respectively compared to uncoated fruit at 2 days storage. Over the next 5 weeks at 6°C there was moderate decrease of oxygen in all fruit except in carnauba where there was 30% low oxygen at 3 weeks storage. The carbon dioxide increased slightly during 5 weeks storage at 6°C in all stored fruit. When fruit were stored at 20°C for one week after 5 weeks at 6°C, in fruit uncoated or dipped in 'Citrus Gleam' or polyethylene O_2 concentration fell to approximately 45% of ambient and CO_2 risen to double compared in fruit at 5 weeks at 6°C. In contrast O_2 and CO_2 in carnauba coated fruit was 9% and over 200% of air. Hence carnauba coating had the same effect on CO_2 but a much greater effect on internal O_2 . Thus it is concluded that while moderate changes in internal atmosphere occurred at 6°C greater changes occurred once fruit were transferred to 20°C. Hagenmaier and Baker (1993) found internal gas composition was highly dependent on coating type. Our findings that polyethylene has high permeability to gases (high level of internal oxygen and low levels carbon dioxide) agrees with the findings of Davis and Hofmann (1973), Ben-Yehoshua, 1967 and Hagenmaier and Shaw, 1991. Shellac ('Citrus Gleam') has low permeability to gases compared to polyethylene and carnauba (Hagenmaier and Baker, 1994). Our results confirm that shellac coating lowered and increased the levels of internal oxygen and carbon dioxide in coated fruit respectively compared to polyethylene although not significantly. Carnauba coating was expected to have a similar effect as polyethylene on the internal atmosphere of coated fruit (Hagenmaier and Baker, 1994) and higher permeability than shellac and resin based products like 'Citrus Gleam' (Hagenmaier and Shaw ,1992; Hagenmaier and Baker, 1993). However our results show carnauba coatings had the most undesirable levels on the internal atmosphere of coated fruit. The active ingredient of the carnauba used in the study is not known although carnauba wax is extracted from *Copernica*.

'Citrus Gleam' coating reduced internal O_2 in order of increasing number of dippings but changes in internal CO_2 were not so consistent (Table 21). The effect of number of dips in polyethylene was not related to the gas internal atmosphere of 'Silverhill' fruit. However the internal (core) oxygen in 'Citrus Gleam' dipped Silverhill' fruit had fallen 100% and carbon dioxide doubled compared with fruit sprayed with 'Citrus Gleam' when observed after 7 days storage at 6°C plus one week at 20°C. Dipping fruit in coating probably forms a thicker layer over the fruit than a spray application which increases resistance to gases flowing in and out of the fruit. Eaks and Ludi (1960), Ben-Yehoshua (1967) and Hagenmaier and Baker (1993) found that internal CO_2 increase and O_2 decreased in relation to thickness of applied coating of shellac. Thus application methods, thickness and type of coating are important factors to be considered when recommending a coating for a particular type of fruit. Spraying rather than dipping in coatings should be the method of any future experiments with coatings.

In the present study mandarin fruit coated either with carnauba or shellac-based 'Citrus Gleam' when cold stored for 3 weeks produced off flavours which was detected by a sensory panel. Off-flavour was probably caused by elevation of ethanol and acetaldehyde as reported by Cohen et al., (1990). In the present study higher levels of ethanol and acetaldehyde measured in fruit coated with carnauba or 'Citrus Gleam' was positively related to low O_2 and high CO_2 in fruit internal atmospheres (anaerobic condition). Therefore there was a shift to anaerobic respiration which increased the volatiles causing off flavour in the two coated treatments. Ahmad and Khan (1989) and Dangyang and Kader (1990) found the decrease in flavour scores during storage of mandarin and orange juice respectively correlated to increases in ethanol and acetaldehyde contents.

The optimal coating should maximally reduce transpiration loss without creating an injurious atmosphere inside the fruit, so the internal atmosphere must be within the range in which there is neither a deficiency of O_2 nor an excess of CO_2 during storage at the range of temperatures to which the fruit would be exposed (Banks et al., 1993). Assessing the performance of surface coating materials for fresh fruit involves weighing desired benefits (including cosmetic, weight loss and modified atmosphere effects) against risks which include anaerobiosis (Banks, 1995), Polyethylene was the most suitable coating to be used for mandarin fruit during long term storage from the present study. Fruit coated with polyethylene had similar levels of oxygen (9.2%) as in uncoated fruit during 5 weeks at 6°C plus one week at 20°C and had no-offlavour at that time. In contrast, fruit coated with carnauba had the greatest modification of internal atmosphere composition although weight loss reduction was similar to other coatings. Fruit coated with either carnauba or 'Citrus

Gleam' produced off flavour (a sign of anaerobiosis) detected by a sensory panel at 42 days storage at 6°C. Wax is not applied postharvest on locally grown citrus in Japan due to safety concerns. Polyethylene wax is permitted in the United States as a protective coating on a number of fresh fruit including citrus (Hagenmaier and Shaw, 1991). Thus mandarin fruit coated with polyethylene probably may have future in Japanese market. Since waxed fruit of mandarin are sold in New Zealand, polyethylene could be one of the waxes recommended.

CHAPTER 6 CONCLUSION

The key to successful export markets for citrus to Japenese market is a high quality product. In particular dessert satsuma mandarin juice need a minimum TSS of 10% and a TSS:acid ratio of 10:1. In this study none of the mandarin fruitharvested over commercial harvest period reached the minimum quality requirement of TSS:acid ratio of a 10:1 at harvest. Fruit from Kerikeri and Gisborne reached a higher TSS:acid ratio compared with fruit from Bay of Plenty. With present cultural practices 'Silverhill' and 'Miyagawa' intended for export to Japan probably need to be harvested late (July) from these districts. Postharvest handling offers an opportunity to harvest fruit earlier (< 1.2% acidity) and cold store it for 3 to 6 weeks to attain desired internal quality.

Satsuma cvs Silverhill and Miyagawa can attain a standard suitable for sale in Japan since the results show the internal quality improvement in both cultivars during the various storage periods at 6°C with a shelf like of one week at 20°C. Since it takes 5-6 weeks shipment from New Zealand for fruit to arrive in Japan, fruit (< 1.2% acidity and 10% TSS) probably could be cold stored in shipment to reach minimum export standard. The TSS:acid ratio increased at storage mainly due to a steady decline in titratable acidity.

Coatings did not improve the internal quality of fruit in satsuma mandarin but controlled significant water loss compared to uncoated fruit. However at the end of 7 weeks storage (6 weeks at 6°C and 1 week at 20°C) weight loss in all waxed fruit of >9% was too high to be acceptable for commercial practice. 'Citrus Gleam' and carnauba coated fruit produced off flavours at 5 weeks storage at 6°C. Fruits dipped in 'Citrus Gleam' produced higher levels of off-flavours than sprayed ones. Thus all trials should use sprays than dipping. 'Citrus Gleam' and carnauba produced undesirable levels of internal atmosphere (low O_2 and High C_o2) and high levels of ethanol. Polyethylene coating looks promising as a coating for mandarin compared to 'Citrus Gleam' and carnauba since it had the desirable benefit of low levels of internal atmosphere changes and no off-flavours.

FURTHER WORK

Future investigations into combined benefits arising from reduction of water loss and moderate permeability to internal gases with application of suitable surface coatings or wrapping would provide useful information for maintaining mandarin fruit quality at storage or shipment.

The changes in the internal quality of promising mandarin cultivars at different maturity levels at various storage periods would add information for export markets of mandarin.

REFERENCES

Ahmad, M. and I. Khan. 1987. Effect of waxing and cellophane lining on chemical quality indices of citrus fruit. Plant Foods for Human Nutrition 37:47-57.

Anderson, C.A. 1966. Effects of phosphate fertilizer on yield and quality of 'Valencia' oranges. Proceedings of Florida State Horticultural Society 79:36-40.

Anon, 1993. Greater Satsuma maturity remit defeated. The Orchardist of New Zealand October 66(9):26-27.

Anon, 1995. New Zealand horticultural exports for the year ending 30 June 1995. The Orchardist of New Zealand November 68(5):36-37.

Baldwin, E.A. 1993. Citrus Fruit, In Biochemistry of Fruit Ripening. eds. Seymour,G.; Taylor, J. and Tucker, G. Chapman and Hall, London.107-149pp

Baldwin, E.A., M. Nisperos-Carriedo, P.E. Shaw and J.K. Burns. 1995. Effects of Coatings and Prolonged Storage Conditions on Fresh Orange Flavour Volatiles, Degrees Brix, and Ascorbic Acid Levels. Journal of Agricultural Food Chemistry 43:1321-1331.

Baile, J.B. 1961. Postharvest physiology and chemistry. In The orange fruit. ed. W.B. Sinclair. University of California Press, Berkeley.

Banks, H.B., B.K. Dadzie and D.J. Cleland. 1993. Reducing gas exchange of fruits with surface coatings. Postharvest Biology and Technology 3: 269-284.

Banks, H.B. 1984. Some effects of Tal Prolong coating on ripening of bananas. Journal of Experimental Botany 35: 127-137.

Banks, N.H. 1995. Surface coatings for fruits and vegetables. The Orchardist of New Zealand Nov 68(10): 52-55.

Bean, R.C. and G.W. Todd. 1960. Photosynthesis and respiration in developing fruits. 1.$^{14}CO_2$ uptake by young oranges in light and dark. Plant Physiology 35:425-429.

Beever, D.J. 1990. Export quality Satsumas need careful handling. The Orchardist of New Zealand March 63(2): 24-25.

Ben-Yehoshua, S. and B. Shapiro, 1981. Effects of pre and post harvest applications of ethylene releasing agents and auxins and individual seal-packing with high-density polyethylene film on coloration of citrus fruit and its quality. Proceeding of the International Society of Citriculture. 1: 226-229.

Ben-Yehoshua, S. 1967. Some Physiological Effects of Various Skin Coatings on Orange Fruit. Israel Journal of Agricultural Research 17:1:17-27.

Ben-Yehoshua, S. 1970. Use of a Physiological Parameter as Means for Operational Control of Application of Orange Skin-coating in Packing Plants. Tropical Agriculture, Trinidad 47. No.2:151-155.

Ben-Yehoshua, S. 1978. Delaying Deterioration of Individual Citrus Fruit by seal-Packaging in Film of High Density Polyethylene 1. General Effects. Proceeding of the International Society of Citriculture :110-115.

Ben-Yehoshua, S., S.P. Burg and R. Young. 1985. Resistance of Citrus Fruit to Mass Transport of Water Vapor and Other Gases. Plant Physiology 79:1048-1053.

Ben-Yehoshua, S. 1969. Gas exchange, transpiration and the commercial deterioration of orange fruit in storage. Journal of the American Society for Horticultural Science 94: 524-526.

Bouma, D. 1961. The development of cuttings of the Washington Navel orange to the stage of fruit set. IV. The effect of different nitrogen and phosphorus levels on fruiting cuttings. Australian Journal of Agricultural Research 12: 1089-1099.

Bower, J.P. 1994. Maturity Indexing. Citrus Journal: 31 July.

Brown, N.S. 1985. Navel Oranges Tree Performance on Various Rootstocks at Manutuke Horticultural Station. The Orchardist of New Zealand 58(7): 317-318.

Burg, S.P. and E.A. Burg. 1965. Gas Exchange in Fruits. Physiologia Plantarum 18: 870-884.

Clements, R.L. 1964. Organic acids in citrus fruits. ll. Seasonal changes in the orange. Journal of Food Science 29: 281-286.

Clements, R.L. 1964. Organic Acids in Citrus Fruits. 1. Varietal Differences. Journal of Food Science 29: 276-280.

Cohen, E., V. Shalom and I. Rosenberger. 1985. The effect of Growing Area, Rootstock, Harvesting Time, Waxing and Storage Temperatures on Postharvest Quality of Murkot Mandarin Fruit. Hassadeh 65

Cohen, E., Y. Shalom and I. Rosenberger. 1990. Postharvest ethanol buildup and off-flavour in 'Murcott' Tangerine fruits. Journal of the American Society for Horticultural Science 115: 775-778.

Cohen, E., Y. Shalom and I. Rosenberger. 1991. Storage temperature, duration and wax coating on the keeping quality of 'Nova' mandarin. International Journal of Tropical Plant Diseases 9: 173-177.

Dangyang Ke and A. A. Kader. 1990. Tolerance of 'Valencia' Oranges to Controlled Atmospheres as Determined by Physiological Responses and Quality Attributes. Journal of the American Society for Horticultural Science 115(5): 779-783.

Daito, H. and Y. Sato. 1985. Changes in the Sugar and Organic Acid Components of Satsuma Mandarin Fruit during Maturation. Journal of the Japanese Society of Horticultural Science. 54(2): 155-162.

Davies, F.S. 1986. Growth regulator improvement of postharvest quality. In Fresh Citrus Fruits. eds. Wardowski, W.F., S. Nagy, and W. Grierson, AVI Publishing, Westport,CT. 80-95pp

Davies, F.S. and L.G. Albrigo. 1994. Citrus. Redwood Books, Great Britain. 254pp.

Davis, P.L. 1971. Further studies of Ethanol and Acetaldehyde in juice of citrus fruits during the growing season and during storage. Proceedings of the Florida State Horticultural Society : 217-222.

Davis, P.L. 1979. Relation of Ethanol content of citrus fruits to maturity and storage condition. Proceedings of the Florida State Horticultural Society : 294-298.

Davis, P.L., W.G.J. Chace and R.H. Cubbedge. 1967. Factors Affecting Internal Oxygen and Carbon Dioxide Concentration of Citrus Fruits. HortScience 2(4): 168-169.

Davis, P.l. and Harding, P.l. 1960. The reduction of rind breakdown of 'Marsh' grapefruit by polyethylene emulsion treatments. Proceeding of the American Society of Horticultural Science 75: 271-274.

Davis, P.L. and R.C. Hofmann. 1973. Effects of Coatings on Weight Loss and Ethanol Buildup in Juice of Oranges. Journal of Agricultural Food Chemistry 21(3): 455-458.

Davis, P.L., B. Roe and J.H. Bruemmer. 1973. Biochemical Changes in Citrus Fruits during Controlled-Atmosphere storage. Journal of Food Science 38: 225-229.

Dawes, S.N. and P.J. Martin. 1991. A comparison of two mid-season and two late-maturing Satsuma mandarins with the standard industry cultivar 'Silverhill'. New Zealand Journal of Crop and Horticultural Science Vol.19: 25-30.

Dixon, J. 1993. Temperature and atmosphere composition influence on color change of apples. MSc Dissertation. Massey Univ. Palmerston North, New Zealand, Dadzie, B.K. 1992. Gas exchange characteristics and quality of apples. PhD Dissertation, Massey University, Palmerston North, New Zealand.

Eaks, I.L. and W.A. Ludi. 1960. Effects of Temperature, Washing, and Waxing on the Composition of the internal Atmosphere of Orange Fruits. Journal of the American Society for Horticultural Science 76: 220-228.

Eilati, S., S.P. Monselise and P. Budowski. 1969. Seasonal development of external color and carotenoid content in the peel of ripening Shamouti oranges. Journal for the American Society of Horticultural Science 94: 346-348.

El-Zeftawi, B.M. 1976. Cool storage to improve the quality of Valencia oranges. Journal of Horticultural Science 51: 411-418.

Embleton, T.W., Jones, W.W. and J.D. Kirkpatrick. 1956. Influence of applications of dolomite, potash and phosphate on quality and composition of 'Valencia' orange fruit. Proceedings of the American Society of Horticultural Science 67: 191-201.

Erickson, L.C. 1968. The general physiology of citrus. In The Citrus Industry. eds. W.Reuther, H.J. Webber and L.D. Batchelor. University of California Press, Berkeley.

Echeverria, E. 1987. Changes in Sugars and Acids of Citrus Fruits During Storage. Proceedings of the Florida State Horticultural Society 100: 50-52.

Ed Echeverria and M.Ismail. 1987. Changes in sugars and acids of citrus fruits during storage. Proceedings of the Florida State Horticultural Society 100: 50- 52.

Erner, Y.; Y. Kaplan; B. Artzi; and M. Hamou. 1993. Increasing citrus fruit size using auxins and potassium. Acta Horticulturae. No 329: 112-119.

Fallahi, E. and D.R. Rodney. 1992. Tree Size, Yield, Fruit Quality, and Leaf Mineral Nutrient Concentration of 'Fairchild' Mandarin on Six Rootstocks. Journal of the American Society for Horticultural Science 117(1): 28-31.

Fallahi, E., J.W. Moon and D.R. Rodney. 1989. Yield and Quality of 'Redblush' Grapefruit on Twelve Rootstocks. Journal of the American Society for Horticultural Science 114(2): 187-190.

Fletcher, W.A.and M. Hollies, 1965. Maturity and Quality in New Zealand Oranges Evaluated. New Zealand Journal of Agriculture 110: 153-160.

Gardner, F.E. and P.C. Reece. 1960. Evaluation of 28 'Navel' orange varieties in Florida. Proceeding of Florida State Horticultural Society 73: 23-28.

Gilfillan, I.M., L.C. Holtzhausen, W. Koekemoer and J.A. DuPlessis. 1971. Picking Season Changes in Valencia Quality Factors. The Citrus Grower and Sub-Tropical Fruit Journal : 11-15.

Goldschmidt, E.E. 1980. Pigment changes associated with fruit maturation and their control. In Senescence in plants. ed. K.V. Thimann, CRC Press. INC, Boca Raton, Florida 276pp.

Gorris, L.G.M.and.H.W.P. 1992. Modified Atmosphere and Vacuum Packaging to Extend the Shelf Life of Respiring Food Products. HortTechnology 2(3): 303-309.

Gorski, P.M. and L.L. Creasy. 1977. Color development in 'Golden Delicious' apples. Journal of the American Society for Horticultural Science 102: 73-75.

Grierson, W.F.W. 1978. Relative Humidity Effects on the Postharvest Life of Fruits and Vegetables. HortScience 13(5): 570- 574.

Grierson, W. and S. Ben-Yehoshua. 1986. Storage of Citrus Fruits In Fresh Citrus Fruits. eds. Wardowski, W.F., S. Nagy and W. Grierson. AVI Publishing, Westport, CT. 379-395p

Grierson, W. and W.F. Wardowski. 1978. Relative Humidity Effects on the Postharvest Life of Fruits and Vegetables. HortScience 13(5): 570-574.

Hagenmaier, R.D. and R.A. Baker. 1993. Citrus Fruit Single or Layered Coatings Composed with Packinghouse-coated Fruit. Proceeding of Florida State Horticultural Society 106: 238-240.

Hagenmaier, R.D. and R.A. Baker. 1995. Layered Coatings to Control Weight Loss and Preserve Gloss of Citrus Fruit. HortScience 30(2): 296-298.

Hagenmaier, R.D. and R.A. Baker. 1994. Wax Microemulsions and Emulsions as Citrus Coatings. Journal of Agricultural Food Chemistry 42: 899-902.

Hagenmaier, R.D. and R.A. Baker. 1993. Reduction in Gas Exchange of Citrus Fruit by Wax Coatings. Journal of Agricultural Food Chemistry 41: 283-287.

Hagenmaier, R.D. and E.S. Shaw. 1992. Gas Permeability of Fruit Coating Waxes. Journal of the American Society for Horticultural Science 117(1): 105-109.

Hagenmaier, R.D. and P.E. Shaw. 1992. Gas Permeability of Fruit Coating Waxes. Journal of the American Society for Horticultural Science 117(1): 105-109.

Hagenmaier, R.D. and P.E. Shaw. 1991. Permeability of Coatings Made with Emulsified Polyethylene Wax. Journal of Agricultural Food Chemistry 39: 1705-1708.

Hall, D.J. 1981. Innovations in Citrus Waxing-An Overview. Proceeding of Florida State Horticultural Society 94: 258-263.

Hansen, E. 1956. Factors affecting post-harvest colour development in Pears. Proceeding of the American Society for Horticultural Science 66: 118-124.

Harty, A.R. and P. Anderson. 1995. Japanese production practices of satsuma mandarins. The Orchardist of New Zealand April 67(3);40-43.

Harty, A.R., P.G. Sutton and C.A. Jagiello. 1992. Stop marketing immature citrus. The Orchardist of New Zealand April 65(3): 13-15.

Harty, A.R. and P.G. Sutton. 1990. Richards Special - A promising mandarin rediscovered. The Orchardist of New Zealand December 63(11): 24-26.

Hilgeman, R.H., J.A. Dunlap and F.O. Sharp. 1967. Effect of time of harvest of 'Valencia' oranges in Arizona on fruit grade and size and yeild the following year. Proceeding of the American Society for Horticultural Science 90: 103-109.

Hilgeman, R.H., J.A. Dunlap and G.C. Sharples. 1967. Effect of time of harvest of 'Valencia' oranges on leaf carbohydrate content and subsequent set of fruit. Proceeding of the American Society for Horticultural Science 90: 110-116.

Huffaker, R.C. and A. Wallace. 1959. Dark fixation of Carbon dioxide in homogenates from citrus leaves, fruits and roots. Proceeding of the American Society for Horticultural Science 74: 348-356.

Ishida, K. 1994. Quality changes in Harvested Winter squash by Enhancement of Calcium Status and by use of surface coatings. MSc Horticulture. Dissertation, Massey University, Palmerston North, New Zealand.

Jahn, O.L. 1976. Degreening of waxed citrus fruit with ethephon and temperature. Journal of the American Society for Horticultural Science 101: 597 599

Jellinek, G. 1985. Sensory evaluation of Food: Theroy and Practice. Ellis Horwood Ltd. 44-55.

Jones, W.W., T.W. Embleton and C.B. Cree. 1962. Temperature Effects on Acid,Brix In Washington Navel Oranges. The California Citrograph :132-134.

Kader, A.A. 1986. Biochemical and Physiological basis for effects of controlled and modified atmospheres on fruits and vegetables. Food Technology. 40 (5): 90-104.

Kader, A.A., R.F. Kasmire., F.G. Mitchell., M.S. Reid., N.F. Sommer.and J.F. Thompson. 1985. Postharvest Technology of Horticultural crops. University of California Press, Berkeley. 192pp.

Kaplan, H.J. 1986. Washing, Waxing and Color- Adding in Fresh Citrus Fruits. eds. Wardowski, W.F., S. Nagy.and W. Grierson, AVI Publishing, Westport, CT.379-395p.

Khalifah, R.A. and J.R.Kuykendall. 1964. Effect of Maturity, Storage temperature, and Prestorage Treatment on storage Quality of Valencia Oranges. Proceedings of the American Society For Horticultural Science 86: 288-296.

Kefford, J.F. and Chandler. B.V. 1970. The Chemical Constituents of Citrus Fruits. Academic Press, New York.

Kester, J.J. and O.R. Fennema. 1986. Edible Films and Coatings: A Review. Food Technology : 47-59.

Knee, M., E.T. Santili and G.S. Hatfield. 1988. Promotion and inhibition by ethylene of chlorophyll degradation in orange fruit. Annals of Applied Biology 113: 129-135.

Koo, R.C.J. and A.A. McCornack. 1965. Effect of irrigation and fertilization on production and quality of 'Dancy Tangerine'. Proceeding of Florida State Horticultural Society 78: 10-15.

Krezdorn, A.H. 1977. Influence of rootstock on mandarin cultivars. Proceeding of International Society of Citriculture 2: 513-518.

Kwak, S.J., Y. Ueda, H. Kurooka and H. Yamanaka. 1992. Effect of gas condition in polyethylene package on the occurence of off- flavour of stored satsuma mandarin fruit. Journal of the Japanese Society for Horticultural Science 61(2): 453-359.

Ladeinde, F. and J.R. Hicks. 1988. Internal atmosphere of onion bulbs stored at various oxygen concentrations and temperatures. HortScience 23: 1035-1037.

Looney, N.E. and M.E. Peterson. 1967. Chlorophyllase activity in apples and bananas during the climacteric phase. Nature 214: 1245- 1246.

Martin, P. 1991. Hot satsumas - will they make it in Japan? The Orchardist of New Zealand June 64(5): 20-21.

Montgomery, R., T.W. Conway and A.A. Spector. 1990. Biochemistry. A Case-Oriented Approach. 5th edition. C.V.Mosby Company, St. Lowis, Beeltimore, Philadelphia, Toronto.

Murata, T. 1977. Studies on the Postharvest Physiology and Storage of Citrus Fruit. Vll. Acid Metabolism in Satsuma Mandarin Fruit during Storage. Journal of the Japanese Society of Horticultural Science. 46(2): 283-287.

Nagy, S. and J.A. Attaway. 1980. Citrus Nutrition and Quality. American Chemical Society, Washington, D.C. 456pp.

Nisperos-Carriedo, M.O., P.E. Shaw and E.A. Baldwin. 1990. Changes in Volatile Flavour Components of Pineapple Orange Juice As Influenced by the Application of Lipid and Composite Films. Journal of Agricultural Food Chemistry 38: 1382-1387.

Nito, N. and M. Iwamasa. 1992. Intensive Cultivation under Plastic Coverage for Off-season Shipping of Satsuma. Acta Horticulturae 321: 400-405.

Oogatki, C. and M. Manago 1977. Studies on the controlled atmosphere storage of satsuma mandarin. Proceedings of the International Society of Citriculture 3: 1127-1133.

Purvis, A.C. 1983. Moisture Loss and Juice Quality from Waxed and Individually Seal-Packaged Citrus Fruits. Proceeding of Florida State Horticultural Society 96: 327-329.

Rajapakse, N.C., N.H.Banks, E.W. Hewett and D.J. Cleland 1990. Development og oxygen concentration gradients in fresh tissues of bulky plant organs. Journal of the American Society of Horticultural Science 115(5): 793-797.

Rasmussen, G.K. 1964. Seasonal changes in the organic acid content of 'Valencia' orange fruit in Florida. Proceeding of the American Society for Horticultural Science 84: 181-187.

Reuther, W. 1973. Climate and Citrus, The Citrus Industry. Reuther, W. ed. Division of Agricultural Science, University of California, California, Barkely.

Reuther, W., G.K. Rasmussen, R.H. Hilgeman and G.A. Cahoon. 1969. A comparison of maturation and composition of 'Valencia' oranges in some major subtropical zones of the United States. Journal of the American Society for Horticultural Science 94 :144-157.

Richardson, A., P. Anderson and T. Dawson. 1991. More heat needed for high quality satsuma mandarins. The Orchardists of New Zealand December 64(11): 26-29.

Richardson, A., P. Anderson, A. Harty, P. Sutton and T. Machin. 1991. Satsumas - ten cultivars compared. The Orchardist of New Zealand March 64(2): 22-25.

Richardson, A., P. Mooney, P. Anderson, T. Dawson and M. Watson. 1994. How do rootstocks affect canopy development. The Orchardist of New Zealand November 67(10): 41-43.

Richardson, A., P. Mooney, T. Dawson, P. Anderson, W.J. Killen and M. Astill. 1993. Satsuma mandarin quality is improved using a reflective mulch. The Orchardist of New Zealand February 66(1):36-38.

Sale, P. 1992. Climate and citrus production. The Orchardist of New Zealand March 65(2): 11-15.

Sale, P.R. 1983. New Zealand Citrus Industry Planning Report. Advisory Services Division, Ministry of Agriculture and Fisheries.

Sandhu, S.S. 1992. Effect of pre-harvest sprays of Gibberellic acid, Vipul, calcuim chloride and Bavistin on the tree storage of Kinnow fruits. Acta Horticulturae 321: 366-371.

Sasson, A. and S.P. Monselise. 1977. Organic Acid Composition of 'Shamouti' Oranges at Harvest and during Prolonged Postharvest Storage. Journal of the American Society for Horticultural Science 102(3): 331-336.

Sinclair, W.B. 1961. Organic acids and buffer properties. Chapter 6. The Orange. ed. W.B. Sinclair. University of California. Division of Agricultural Sciences, Berkeley.

Sinclair, W.B. and R.C. Ramsey. 1944. Changes in the organic acid content of 'Valencia' oranges during development. Botanical Gazette 106: 140-148.

Sites, W. and H.J. Reitz. 1955. The variation in individual 'Valencia' Oranges from different locations of the tree as a guide to sampling methods and spot picking for quality. Part ii. Titratable acid and the soluble solids-Titratable acid ratio of the juice. Proceeding of the American Society for Horticultural Science 55: 73-80.

Smith, P.f. and G.K. Rasmussen. 1960. Relationship of fruit size, yield and quality of Marsh grapefruit to potash fertilization. Proceeding of Florida State Horticultural Science 73: 42-49.

Smith, S., J. Geeson and J. Stow. 1987. Production of Modified Atmospheres in Deciduous Fruits by the Use of Films and Coatings. HortScience Vol22(5): 772-776.

Ting, S.V. and J.A. Attaway. 1971. Citrus Fruits, The Biochemistry of Fruits and their Products. ed. A.C. Hulme . Academic Press, New York. 157-159pp

Trout, S.A., E.G. Hall and S.M. Sykes. 1953. Effects of Skin Coatings on the Behaviour of Apples in Storage. Australian Journal of Agricultural Research 4: 219-231.

Vines, H.M., W. Grierson and G.J. Edwards. 1968. Respiration, Internal Atmosphere, and Ethylene Evolution of Citrus Fruit. American Society for Horticultural Science 92: 227-234.

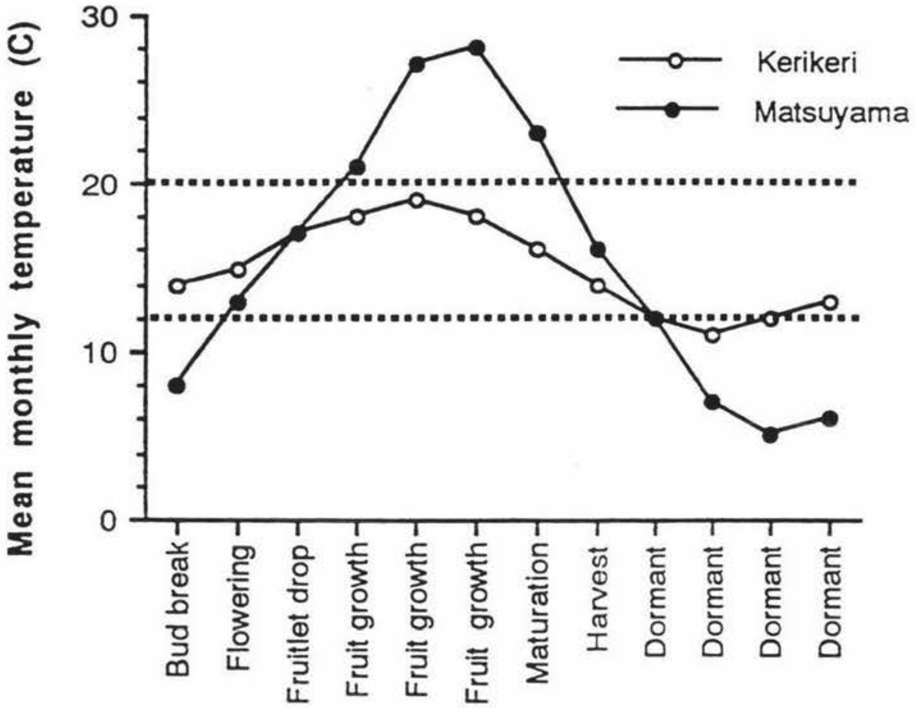
Wills, B.H., T.H. Lee, D. Graham, W.B. McGlasson and E.G. Hall. 1989. Postharvest: An Introduction to the physiology and handling of fruit and vegetables. New South Wales University Press, New South Wales, Australia.

Woods, J.L. 1990. Moisture loss from fruits and vegetables. Postharvest News and Information Vol.1 No.3: 195-199.

Yen, C. and K.E. Koch. 1990. Developmental Changes in Translocation and Localization of ^{14}C-labelled assimilates in Grapefruit: Light and Dark CO_2 Fixation by Leaves and Fruit. Journal of the American Society for Horticultural Science 115(5): 815-819.

Yuda, E., H. Kurooka and S. Nakagawa. 1981. Search for efficient phosphorus fertilization. Proceeding of the International Society of Citriculture 2:537-539.

Appendix I



Mean monthly temperature during each growth phase in Kerikeri, New Zealand and Matsuyama, Japan. (Richardson et al., 1991).

APPENDIX II

RECORD SHEET: Sensory Evaluation Project

roduct: Mandarin juice cultivar: Miyagawa

ame: ______________________________ **Date:** ______________

nstructions:

You have been given several coded samples of mandarin juice. Please evaluate their taste according to the previously defined characteristics below, and in the order stated. Evaluate a sample for all 3 characters before moving onto the next sample. Place a number in the box that best describes the sample.

cidity

Very low 0	1	2	3	4	5	Very acid 6

Sample:

				REF SCORI
				5

weetness

Very low 0	1	2	3	4	5	Very sweet 6

Sample:

				2

Mandarin Flavour

Absent 0	1	2	3	4	5	Very strong 6

Sample:

				3

eneral Comments: Note any additional taste characteristics about any of the samples (i.e. use own descriptive terms).

____

____

Thank

L. Pra

____

APPENDIX III

RECORD SHEET: Sensory Evaluation Project

'roduct: Mandarin juice cultivar: Silverhill

ame: ______________________________ **Date:** ______________

nstructions:

You have been given several coded samples of mandarin juice. Please evaluate their taste according to the previously defined characteristics below, and in the order stated. Evaluate a sample for all 3 characters before moving onto the next sample. Place a number in the box that best describes the sample.

cidity

Very low 0	1	2	3	4	5	Very acid 6

Sample:

				REF SCORI
				4

weetness

Very low 0	1	2	3	4	5	Very sweet 6

Sample:

				3

Aandarin Flavour

Absent 0	1	2	3	4	5	Very strong 6

Sample:

				2

eneral Comments: Note any additional taste characteristics about any of the samples (i.e. use own descriptive terms).

____

____

Thank :

L. Pra

____

APPENDIX V

RECORD SHEET: SENSORY EVALUATION

Product: Mandarin Juice

Name: ______________________________ **Date:** ______________

Instructions:

Please taste the several coded samples of mandarin juice provided and place a tick beside the words that best describe your opinion of the sample.

Sample:							
Like extremely							
Like slightly							
Neither like nor dislike							
Dislike slightly							
Dislike extremely							

Why did you rate the samples this way?

Sample:

APPENDIX IV

EVALUATION PROCEDURE: Liquid Product

(All Sessions)

AIM: To taste and score samples of mandarin juice for sweetness, acidity and flavour.

1. If possible, do not eat or smoke 1 hour before testing.

2. Rinse your mouth thoroughly (deionised water).

3. Taste the reference sample. Rinse.

4. Taste samples on tray from left to right. Sample numbers on the tray should match sample numbers on your evaluation sheet. If they do not, please let us know.

5. Please evaluate each sample in the same manner, taking a similar but modest quantity into the mouth.

6. Rinse mouth out thoroughly after each sample. This is to remove any flavour residue.

7. Be careful not to muddle the samples.

8. Record all 3 characteristics for a test sample, before tasting the second sample. Make your scoring clear. We must have an answer.

9. It is preferable to score after you have tasted each sample once. If you must retaste, please use the same procedure as before.

10. Finally please comment on any differences, similarities, and general opinions.

L. Prasad

Appendix V1

Gas concentration in internal core and sub-epidermal surface of mandarin after 51 hours storage at 6°C.

Treatment	Oxygen(%)	Carbon dioxide(%)
Core	1.29 ± 0.11	19.68 ± 0.14
Sub-epidermal	1.03 ± 0.08	20.02 ± 0.13
Significance	ns	ns